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RESEARCHES ON

THE EARTH'S ATMOSPHERE.

WORKS BY THE SAME AUTHOR

Familiar Letters on some Mysteries of Nature. (London, 1876.)

Phosphorescence, or the Emission of Light by Minerals, Plants, and Animals. (London, 1862.)

Noctilucine, the Phosphorescent Principle of Luminous Animals. (Pamphlet from the *Chemical News*, 1875.)

The Utilisation of Minute Life: Practical Studies on Insects, Crustacea, Mollusca, etc. (London, 1864.)

Meteors, Aërolites, and Falling Stars. (London, 1867.)

La Force catalytique, Études sur les Phénomènes de Contact. (*Gold Medal*, Société Hollandaise, Haarlem, 1858.)

Phénomènes météorologiques observés sur le Littoral de la Flandre occidentale. (From the *Comptes Rendus* of the Paris Academy, 1857.)

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Sur les Propriétés optiques des corps appliquées à l'analyse. (*Gold Medal*, Société Royale des Sciences Médicales et Naturelles, Bruxelles, 1868.)

Outlines of a new Atomic Theory. (4th Ed. London, 1886. Pamphlet.)

Traité de Chimie à l'usage des Photographes. (1 Vol. Paris, 1864.)

Explosion et Chute des Météores. (*Comptes Rendus*, Paris, 1869.)

Origine de l'oxygène atmosphérique. (*Id.*, 1893 and 1895.)

Agricultural Chemistry of the Sugar Cane. (3rd Ed. Manchester, 1884.)

Mémoire sur la Fécule. (Bruxelles, 1855. Pamphlet.)

Health Notes and Curiosities of Medical Science. (1 Vol. London, 1898.)

Voice and Violin. (1 Vol. London, 1898.)

Famous Violinists. (1 Vol. London, 1896.)

Scenes from the Reign of Louis XVI. (London, 1878.)

(For other Writings, see "*The Scientific and Literary Works of Dr. T. L. Phipson, with a short Biographical Notice*," by C. J. Bouverie (London, Wertheimer, 1884), and *Catalogue of Scientific Papers of the Royal Society of London*, Vol. IV. and Vol. VII.)

RESEARCHES

ON THE

PAST AND PRESENT HISTORY

OF THE

EARTH'S ATMOSPHERE

Including the Latest Discoveries and their Practical Applications

BY

DR. THOMAS LAMB PHIPSON

AUTHOR OF

"METEORS, AËROLITES, AND FALLING STARS"; "PHOSPHORESCENCE, OR THE EMISSION OF LIGHT BY MINERALS, PLANTS, AND ANIMALS"; "THE UTILIZATION OF MINUTE LIFE"; "FAMILIAR LETTERS ON SOME MYSTERIES OF NATURE"; "HEALTH NOTES AND CURIOSITIES OF MEDICAL SCIENCE "VOICE AND VIOLIN," ETC.

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To

FRANK RUTTER, Esq., B.A. (Cantab.)

THIS LITTLE WORK

IS AFFECTIONATELY INSCRIBED BY

THE AUTHOR

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PREFACE.

THIS little work is to a great extent the result of my own observations, which have spread over a considerable number of years; but I have also availed myself largely of the labours of others, in order to make it more complete, and more useful; for, as Benjamin Franklin said, "*Knowledge is only valuable in proportion as it can be rendered useful to mankind.*"

I owe to my excellent father, to whom I dedicated one of my former works, everything that could foster the prosecution of travel and research, and, though I have not taken full advantage of the excessive liberality which he accorded to all his children, and cannot recall his memory without acknowledging the immense debt of gratitude with which it is associated, yet I trust that my numerous writings will prove "useful to mankind" for many years to come. However, his kindness and foresight have enabled me to devote my life to scientific pursuits, music, and literature, thus doing all he could to make it a life of happiness and contentment in spite of the sorrows and afflictions to which we are all subject in this world, and I have striven to make it also a useful life.

The present volume contains the results of the latest

discoveries connected with the vast aërial ocean which encircles the Earth; the physical and chemical properties of the air; its geological history as far as we can trace it into the remotest ages of the past, and the useful deductions that can be drawn from all these facts.

My discovery of the origin of atmospheric oxygen, made known in a series of papers published from 1893 to 1895 (*Chemical News*, London; *Comptes-rendus*, Paris), and the curious results of that discovery, induced me to write this book, as so much interest is now taken in the subject, in all parts of the world.

In the *Philosophical Magazine* for September and October 1900 are two papers by Mr. John Stevenson, M.A., communicated by Professor G. F. FitzGerald, F.R.S., on the chemical and geological history of the atmosphere, in which allusion is most indulgently made to "Dr. Phipson's beautiful and interesting experiments," and in which Lord Kelvin's views are discussed. After a very long and interesting discussion, Mr. Stevenson confirms my opinion, declaring that "there was a time when there was no free oxygen upon the Earth," and also that "our present supply of free oxygen has been all produced by the action of sunlight on vegetation," which is precisely what my experiments and observations have established.

CASA MIA, PUTNEY, LONDON.

RESEARCHES ON

THE EARTH'S ATMOSPHERE.

INTRODUCTION.

The Science of the Atmosphere—Its Numerous and Important Applications—Origin of Modern Chemistry—The Theory of Combustion—History of the Chemical Composition of the Air—Discovery of the Barometer.

THE Science of the Atmosphere embraces not only the whole domain of *Meteorology*—the laws that determine the distribution of temperature, the cause of winds and cyclonic storms, the formation of fogs, clouds, dew, rain, snow, and hail, luminous manifestations due to electricity, the phenomena of thunderstorms, *ignis fatuus*, and fire-springs, phosphorescent glows, mirage, halos, aurora, waterspouts, avalanches, and glacier movement, sand and dust storms, etc.—but, also, the realms of *Physical Geography*, *Geology*, *Chemistry*, and *Physiology*—the destructive action of the air upon the Earth's surface, by its physical or mechanical action, and by its chemical action; the phenomena of respiration in Plants and Animals, and its important consequences.

Hence the study of the Atmosphere includes certain branches of *Medicine*, antiseptic *Surgery*, and *Hygiene*, establishing the laws of *Climatology*, by which the practitioner is guided in the choice of residence for invalids. It also enables him to effect the promotion of health, and prevention of disease, by the detection of impure, noxious air, and by applying the art of rendering it wholesome.

Moreover, it embraces, also, certain practical portions of *Astronomy* and *Physics*—the laws of reflection, refraction, interference, absorption, pressure, electric condition, and magnetism.

It is, indeed, a vast field of inquiry, and one that is practically inexhaustible; full of surprises inciting to research, and leading to endless useful applications.

The Chemist and the Naturalist, the Astronomer and the Physician, are alike interested in acquiring the most perfect knowledge of the nature and phenomena of our atmosphere, which knowledge forms the basis of the greater portion of the sciences, and promotes the prosperity of the human race.

The history of Chemistry—the dawn of scientific chemistry—is intimately connected with this subject, for modern Chemistry, with all its marvels of industry and invention, may be said to date from the discovery of oxygen. The advancement of the mechanical arts, promoted by the discovery of the barometer and its laws, is no less dependent upon an intimate acquaintance with the properties of that vast aërial envelope which encircles our globe, and is generally supposed

to extend to a height of some forty-five miles from the Earth's surface.

The knowledge of the chemical composition of the air is closely connected with the phenomenon of combustion—the most wonderful of all the phenomena of Nature—the theory of which forms the basis of modern science, and governs its useful applications to the wants of man. The ancients imagined a certain elementary body called *fire*, which possessed the property of devouring other bodies and converting them into itself. According to this view, which is still held by our domestic servants, when we set fire to a grate of coals we bring a small portion of the element fire which immediately begins to devour the coal and convert it also into fire. Whatever part of the coal is not fit to be this food is left behind in the form of ashes.

It was in 1665 that the celebrated English philosopher Dr. Hooke (*Micrographia*, p. 103) first found that there exists in the Atmosphere a certain substance which is like that fixed in saltpetre. The French physician Jean Rey held a somewhat similar opinion thirty-five years previously.[1] In 1675 Hooke's opinion was adopted and extended by Mayow, a young man of Oxford, who published a pamphlet on the subject: *De sal-nitro et Spiritus nitro-aëreo*, which is now celebrated in the annals of Science.

[1] But about a century before this, the physician to Henri IV., Joseph Duchèsne, called Quercitanus, a disciple of Paracelsus, who was also the inventor of *laudanum*, and the discoverer of the *gluten* of wheat flour, got the first glimpse of nitrogen. It was about the year 1573 he said that "saltpetre contains an air which extinguishes

Beccher, and his follower Stahl, came next with a singular theory (*phlogiston*) that threw men's minds, for a time, out of the correct line; and, strange to say, this phlogistic theory was kept up by Priestley, whose experiments on air, with those of Schéele and Lavoisier, finally led to the foundation of modern Chemistry.

I cannot in this work devote space to the purely chemical investigations which gradually led us to a knowledge of the various gases which compose the Atmosphere. They must be sought for in treatises on the history of Chemistry and Physics. I can only say that, like all great discoveries, this knowledge was derived from the labours of a large number of ingenious men, among whom the most conspicuous are Van Helmont (of Brussels), Jean Rey, Bayen, Hooke, Mayow, Hales, Stahl, etc. To Priestley, Schéele, and Lavoisier is due the discovery of oxygen; Black (of Glasgow) discovered the nature of carbonic acid. Nitrogen was actually discovered in 1772 by Dr. Rutherford, then Professor of Botany in Edinburgh (*De Aere mephitico*). Oxygen was discovered about the same time by Priestley, Schéele, and Lavoisier. In 1773 the latter gave us the *first analysis of the air* (finding 27 to 28 *per cent.* of oxygen, instead of 21). He began his researches in

the flame of a candle" (*Clavis philosophorum* in *Theatrum chemicum*, iv. 1141, and Hoefer, *Hist. de la Chimie*, i. 471).

In very ancient times Hippocrates recognized in air his "*pabulum vitæ*" (oxygen), and Democritus knew that it contained a *vital principle* which fixed itself in the body during the act of breathing. (See Aristotle, *De Respiratione.*)

1770, and finally announced in 1774 that "*in every case of combustion oxygen combines with the burning body,*" and from that moment the Science of Chemistry was revolutionized, or, rather, created. Yet years elapsed before he could make a single convert to his views!

The labours of Cavendish on hydrogen (1774), and the speculations of James Watt and others, led to the knowledge of the composition of water. "Ozone," or allotropic oxygen, was discovered by Schœnbein of Basle in 1845, and "argon" (or "allotropic nitrogen"?) by Rayleigh and Ramsay in 1894.

The ancients, with Aristotle, considered air to be one of the "four elements": fire, earth, air, and water. It was also believed to have no weight.

In the early part of the seventeenth century an obscure apothecary named Brun, living in the little town of Bergerac, in France, noticed that when tin was melted over a hot fire, it formed a kind of earth (or, as we should now say, an *oxide*), and *gained in weight.* He asked a medical man of his acquaintance, Dr. Jean Rey, who practised at the neighbouring village of Bugue, in Périgord, how he would explain this, and the doctor repeated the experiment several times. Finally, in 1630, he published a now celebrated pamphlet on the question, in which he declared that tin, when heated, *absorbed air* and *increased in weight.*

This was a remarkable conclusion to arrive at, for in those days air was supposed to have *no weight.*

More than a century later, when this pamphlet by Jean Rey was quite forgotten, another French observer,

named Bayen, found that the same curious phenomenon occurred with mercury, and he concluded that all metals increased in weight when they were calcined. Finally, the celebrated Lavoisier repeated this experiment with mercury, and found that metals *only absorb a portion of the air*, that portion now known as *oxygen gas*. He thus made the first analysis of atmospheric air, as I have already stated.[1]

The weight of the air was discovered in the following singular manner by the illustrious Galileo in 1640, and his opinion was soon confirmed by Torricelli (his pupil) and by the French philosopher Pascal.

Galileo carefully weighed a large vessel full of ordinary air, and then the same vessel full of compressed air. A difference of weight was noticed, and this showed that the air was a body possessed of weight. Not long afterwards, some well-sinkers at Florence endeavoured to get water to rise more than 32 feet in a pump, and failing to do so, they asked Galileo the cause of this failure. In those days the rising of water in a pump was said to be due to the fact that "nature

[1] Nevertheless, it has now been ascertained that this experiment is much older than has hitherto been supposed. It has been discovered that Eck von Sulzbach, a man usually confounded with the German alchemists of the latter part of the fifteenth century, was really the first to notice that metals increase in weight when calcined. His experiment was made with mercury, and with an amalgam of silver, and he distinctly states that this increase in the weight of the metal after calcination is due "to a spirit which fixes itself to the body of the metal," and he also says that when the latter "is distilled, this spirit is set free." Eck von Sulzbach made his second experiment in 1489, so that these facts had been ascertained nearly three hundred years before Lavoisier's experiment. (Compare Dr. F. Hoefer, *Hist. de la Chimie*.)

abhors a vacuum"; and to explain the failure just alluded to, Galileo is reported to have replied: "Yes, nature abhors a vacuum, up to 32 feet, but not beyond."

This little incident set his pupil, Torricelli, thinking over the problem. He imagined the rising of the water in the pump was due to pressure (or weight) of the air, and that this pressure was only equal to a column of 32 feet of water. He took a long tube of glass, filled it with another liquid, mercury, turned it upside down, and allowed its open end to rest on a bath of that metal. He saw that the column of mercury stood at a height of about 13½ times less than that of the column of water in the tube of the pump, and as mercury is about 13½ times heavier than water, it was evident that the same cause acted in both instances, and *that cause was the weight* (or pressure) *of the air.*

Such being the case, the mercury in the glass tube should stand lower on the summit of a high mountain than in the valley, since it would have a less weight of air over it. This was proved to be so, by Pascal and Perrier, and so the barometer became at last one of the most useful of physical instruments in the hands of the meteorologist, the chemist, the physician, the sailor, the farmer, and the engineer.

In bringing forward these modest contributions to so vast a field of research and observation, I must solicit a large amount of indulgence on the part of my readers. It is not my desire simply to reproduce here what is to be found in standard works on Meteorology, but to give, as well as I can, the results of my own personal obser-

vations with as many new facts as possible, whilst I rely, for the rest, on the useful and interesting nature of the facts recorded.

I trust that my little work will thus help to diffuse more exact knowledge with regard to the nature and properties of atmospheric air, and so contribute to promote, in many ways, the welfare of mankind.

The atmosphere, as we know it at the present day, forms over the surface of the globe a vast layer of invisible gas, extending to a great height, and charged with emanations of all kinds, but chiefly of aqueous vapour. When we subtract from it this aqueous vapour, and a minute amount of carbonic acid, it is found, in all parts of the world, to consist of a mixture of two gases, nitrogen and oxygen, in the proportion of 79 of the former to 21 of the latter.[1]

[1] The new gas called "Argon" recently discovered in small quantity in the air by Lord Rayleigh and Prof. Ramsay, to which I make reference in another part of this little work, appeared to be a peculiar form of nitrogen, similar to what ozone is as regards oxygen. I was the first to call attention to this circumstance in a note inserted in the *Chemical News* (1894), and my opinion has been since confirmed by Prof. Berthelot of Paris (*Comptes-rendus*, March 1895). Prof. Dewar seemed to be of the same opinion. It might also be *a compound of carbon and nitrogen*, containing half as much carbon as cyanogen; such a compound would have the same specific gravity. But it is impossible at the present time to speculate upon the real nature of this new substance, as so very little is known about it. One hundred volumes of atmospheric air contain less than one volume of "argon," and its name is due to its *inert nature*, its negative properties being apparently greater than those of nitrogen itself. But whatever may be its real nature, argon is only present to such an insignificant amount (barely 1 *per cent.*) that it can exert no influence upon the general propertios of the air, nor, considering its inert character, upon animal or vegetable life.

PART I.

THE EARTH'S ATMOSPHERE IN REMOTE GEOLOGICAL PERIODS.

CHAPTER I.

The Atmosphere in the earliest Epochs of the Globe—It contained no Free Oxygen—The views of Koene, Berzélius, Mulder, Liebig, Dumas, and Ch. Martins—The Author's Observations and Experiments—Plants were the first producers of Atmospheric Oxygen—Fixation of Carbon in the Earth's Strata—Diminution of Carbonic Acid in the Air—The changeable Composition of the Atmosphere—Gradual increase of Oxygen.

WATER and air—the first a chemical compound, the second a mixture only—have been considered by modern authors as the *Residues* left in primeval times after the cooling of the Earth, residues of stupendous chemical action, the formation of which rendered the surface of the globe fit for the existence of organized beings.

But, was the air in those primitive periods such as we now know it?

Everything points to the fact that the chemical constitution of the atmosphere has varied in successive ages, just as the various *flora* and *fauna* of the Earth have changed.

The presence of certain combustible substances, such as iron pyrites, copper pyrites, molybdenite, graphite, etc., in the primitive rocks, long ago appeared to me to prove that *no free oxygen could have been present in the atmosphere* when these rocks were formed.

The late Prof. C. J. Koene, of the University of Brussels, admitted that *carbonic acid* must have been present in the ancient atmosphere of the globe in much larger quantities than at present, especially during the period of the coal flora, which notion appears to be proved by the enormous residues of coal and anthracite, as compared with the more recent deposits of lignite and peat.

Four great names appear also in connection with this subject: Jean Baptiste Dumas and Justus von Liebig on the one hand, Berzélius and Mulder on the other. The two former appear to have considered the chemical composition of the atmosphere of our globe to be permanently fixed for an indefinite period, and, perhaps, they admitted it always to have been so since the first appearance of life upon the Earth, resting their views on the fact that whilst plants give out oxygen and absorb carbonic acid, animals absorb oxygen and reject carbonic acid. Dumas and Liebig looked upon the animal and vegetable kingdoms as indispensable one to the other, and believed that their mutual action upon the atmosphere would keep its composition constant.

Charles Martins, a celebrated French naturalist, and a contemporary of Dumas, criticized this compensation

theory, by pointing out the extremely minute quantity of air which is affected by the respiration of plants and animals, as compared with the vast bulk of oxygen in the atmosphere. Making use of Dumas' own calculations, he shows that the atmosphere containing, say, 134,000 cubic measures of oxygen, the entire animal world only consumes about 15 of these in an entire century. Hence, he says, "The constant composition of the air *does not depend upon a pretended equilibrium between the respiration of plants and animals*, but upon the fact that the quantity of oxygen consumed by animals is out of all proportion to that contained in the entire atmosphere."[1] Berzélius felt convinced that *oxygen must gradually diminish* in the air, for, he declared he knew of "no de-oxydizing process sufficiently great and general to set at liberty all the oxygen which combines every instant with combustible material."[2]

The great Dutch chemist, Mulder, went still further; he insisted upon the enormous production of carbonic acid by the respiration of animals, fermentation, volcanic action, and human industry, and noted the constantly increasing destruction of forests, those vast manufactories of oxygen gas. He concluded that *carbonic acid must increase*, and that *oxygen has continued to decrease* since the first appearance of life upon the Earth.

With regard to volcanic action, I myself have calculated roughly, on the spot, the quantity of car-

[1] *Météorologie et Physique du Globe.*
[2] *Traité de Chimie*, vol i.

bonic acid produced by a small chalybeate spring near Neubau in the principality of Waldeck (Germany) in the year 1865. It was somewhat over a pound in weight per hour, or about half a hundredweight in the twenty-four hours. And this is only one of some thousands of similar springs scattered over the surface of Europe alone.

Dr. Koene upheld a precisely contrary opinion to those just mentioned: he admitted that the *carbonic acid and nitrogen* of the atmosphere have *never ceased to diminish* since the origin of living creatures, whilst *the relative amount of oxygen has gone on increasing in proportion.*

I shall show that oxygen has really increased; and, such being the case, nitrogen and carbonic acid will, of course, appear to have diminished.

It seemed very evident to me that as there could have been *no free oxygen in the primitive atmosphere of the Earth*, the first living beings must have been formed in an air composed of *nitrogen*, containing some carbonic acid and vapour of water. They must have been *anaërobic*, that is, *capable of existing without free oxygen*; and it is interesting to note that some fifteen years after Koene professed his theory, Pasteur actually discovered anaërobic microbes and described their functions in fermentation, etc.

It then struck me that *plants were the first producers of atmospheric oxygen*, and that they have produced it in constantly increasing quantities as ages rolled by, until the air acquired the composition it now has; and,

finally, I undertook a long series of experiments[1] with the view of testing this theory.

By adopting the views of Lamarck and Geoffroy de St. Hilaire, followed up by Darwin and his friends, it would be easy to admit that these *first producers of free oxygen*—these *anaërobic* beings, consisting, in the first instance, of the lower orders of plants such as the *Protococcus*, or unicellular algæ, on which I experimented many years ago, and found that, weight for height, they produced far more oxygen than the higher plants—would, in process of time, as the quantity of oxygen in the air became greater, gradually become more or less *aërobic*, and finally completely so. . . .

Ferdinand Hoefer's opinion that plants first appeared is stated in the following lines:—

"Starting from the theoretical view of the gradation of organized beings, and looking upon *vegetable life as a necessary condition of animal life*, the former must, consequently, have appeared before the latter."[2]

Alexander von Humboldt made a rather weak attempt to disprove this by alluding to the fact that the Esquimaux live almost exclusively on fish and cetacea.

An immense quantity of *carbon* is fixed in the Earth by the remains of plants and animals, and never returns to the air. Nitrogen is also supposed to be extracted from the atmosphere to form nitrates

[1] *Comptes-rendus de l'Acad. des Sc.*, Paris, Août 1893 and 1895, and *Chemical News*, London, 1893 and 1894.

[2] *Histoire de la Botanique.*

and ammonia; but I shall show that this is not the case.

Oxygen alone remains in relatively larger and larger proportions; it has increased since the first living beings appeared, and its present *maximum* coincides with *the maximum development of the central nervous and brain tissue* of the animal world.

As for carbonic acid, for the last half century chemists have noted it as only 6, 5, and 4 parts on 10,000 parts (volumes) of air. The latest determinations by Reiset (a very careful chemist, pupil of Boussingault, and one of the editors of Millon's well-known *Annuaire*), made at a country place, many miles from Paris, gave *only* 3 *volumes of carbonic acid on* 10,000 *volumes of air* in 1889, and he could not get a fraction more. Pelouze, master of the Mint at Paris, who was one of the most expert chemists of modern times, held the opinion that the atmosphere *might be undergoing very slight variations which will only become appreciable to analysis after a great number of years.* Baudrimont, and other eminent chemists have held similar views, admitting that the so-called *fixity of composition is only apparent*, not real.

CHAPTER II.

Respiration in the Lowest Forms of Life—Eremacausis on the Earth.

ANATOMY and physiology cannot teach us how *respiration* is effected in the lowest creatures in the scale of life, those which are supposed to have been the first produced. All vestiges of a respiratory organ are absent, unless it be the cell wall or outer envelope that breathes.

Until my recent experiments were made (which, however, were preceded in another direction by those of Pasteur, when he discovered the *anaërobic* ferments), no one could say whether these beings require *free oxygen* or not; though this could be proved for higher organisms, such as fish and tadpoles, which live in water. I found that the microscopic unicellular algæ, *Protococcus pluvialis*, *P. palustris*, etc., carry on their respiratory functions much as the higher organized plants do, but with more energy. In such animals as *Holothuria tubulosa*, the functions of respiration is little, if at all, separated from that of the intestine: water is sucked in, three times a minute, and remains about twenty seconds in the animal's body.

It is not yet known with certainty whether these lower forms of life may be able to derive oxygen from water, or carbonic acid, or both. But it is evident that oxygen is essential both for plants and animals, however low in the scale; in fact, that oxygen and life seem to be synonymous terms in this respect; only, we must distinguish between *oxygen in combination*, and the *free oxygen of the atmosphere.*

Koene's ingenious theory to which I have alluded is based upon the *incomplete eremacausis* of organic matter which is confided to the earth, and protected from the action of the air, by which means enormous quantities of *carbon* have always been, and are still being, slowly subtracted from the atmosphere. He did not believe that this element can be supplied from without—from cosmic space—and it thus disappears for ever from our atmosphere.

But is this eremacausis, or slow combustion, really so incomplete? Is not carbonic acid returning in immense quantities to the atmosphere, not only by the respiration of animals and volcanic action, but by the agency of man himself? In times, perhaps not so very far distant, will not the whole of those vast deposits of coal and lignite, formerly taken from the air, return to the atmosphere again as carbonic acid? And if forests continue to be constantly annihilated, as Mulder remarked, to make room for clay and stone buildings, will not carbonic acid increase, until it once more predominates, as it is supposed to have done in primitive times?

It seems evident to me that *vitality*, nervous power,

and *atmospheric oxygen* have increased together, from the earliest ages of the globe, and that *the history of this increase can be read in the records of the Earth's strata.*

Although, as will be seen presently, my researches bear out this theory of the increase of oxygen in the atmosphere, it presents, at first sight, a curious paradoxical aspect: oxygen is admitted to be the product of life, whilst it is the condition of life, and its final predominance in the atmosphere will, perhaps, be the cause of universal death. Certainly this appears highly paradoxical; and it may be questioned whether the solution of such problems is not beyond the powers of Science, like all those which touch upon creation. But, as I have already remarked, we must distinguish between oxygen, and *free oxygen* in the atmosphere.

CHAPTER III.

Plants are essentially *Anaërobic*—Experiments by the Author—Primitive Atmosphere of the Earth—Vegetation in this Primitive Atmosphere and in other Gases.

ADMITTING that *no free oxygen* could have existed in the atmosphere when life first appeared upon our globe, and that this atmosphere must then have consisted of nitrogen, containing more or less carbonic acid, and vapour of water, it follows that *atmospheric oxygen* must originally have been derived from the vital functions of inferior plants such as the unicellular algæ, which were the first created beings, having the power, under the mysterious influence of the solar rays, of separating it from its compounds, carbonic acid and water. Granting that the ancient cryptogamic plants of the Coal flora period, for instance, could thrive at higher temperatures, and in an atmosphere far richer in carbonic acid than that of our own day, it became very interesting to ascertain to what extent our modern plants can vegetate under similar circumstances.

It was in making experiments to this effect I discovered that *all plants are essentially anaërobic.* I have caused them to vegetate in carbonic acid, in

hydrogen, and in nitrogen, as well as in a mixture of nitrogen, carbonic acid, and vapour of water—representative of the "primitive atmosphere" at the time life first appeared.

I was thus gradually led to conclude that the primitive atmosphere of the Earth was *nitrogen*, into which volcanic action poured more or less carbonic acid and vapour, and that *after vegetable life appeared, free oxygen made its appearance in the air, and has increased in quantity from those primitive times to the present day.*

I had noticed many years ago that certain plants (willow, lilac, etc.) did not thrive in pure carbonic acid, and I concluded that the diminished quantity of this gas now existing in our atmosphere was the condition that suited them best.

In experiments carried out more recently, I have placed various other plants, such as *Poa*, *Agrostis*, *Myosotis*, *Antirrhinum*, and *Convolvulus* in an atmosphere composed of pure carbonic acid, and in one composed of air with about a hundred times more of this gas than exists in our atmosphere at the present day. All other conditions of vegetation were normal: there was ample water, mineral elements, and an appropriate temperature ranging from 59° to 70° Fahr., during the whole course of the observations.

It was not long before I found that my plants *could exist* for many days, or even weeks, in an atmosphere of *pure carbonic acid,* but they did not thrive; cell formation became slower and slower, in spite of a constant good light.

In an atmosphere that contained so much carbonic acid that an *animal* exposed to it would perish in a *few minutes*, all my plants lived for many weeks, and appeared healthy.

In an atmosphere containing one hundred times as much carbonic acid as in the natural state of the air in our day, my plants flourished remarkably well for the whole time that the experiment lasted—a month, or six weeks.

It was thus rendered highly probable that in former geological periods there existed plants which could flourish in an atmosphere excessively rich in carbonic acid, and that the quantity of that gas in the air has really decreased from those times to the present day; the loss being represented by the vast deposits of peat, lignite, coal, and anthracite found in the strata of the Earth.

I also made some experiments in an atmosphere of pure hydrogen, out of curiosity to see what would happen when plants were placed in such a medium—a gas which many have looked upon as the vapour of a metal—all other conditions remaining normal, namely, water charged with carbonic acid, and containing the necessary mineral ingredients, and a steady source of daylight.

The plants I placed in this atmosphere of pure hydrogen were *Convolvulus arvensis* (a plant which is very convenient for observation of this kind), and a small specimen of *Antirrhinum majus*. For the first few days nothing peculiar was noticed. From

the 27th May to the end of the month a slight bleaching of the leaves only was apparent, but by 3rd June a singular phenomenon occurred: *the volume of gas began to diminish,* and in the course of another month the *atmosphere of hydrogen* in which the *Convolvulus* vegetated was absorbed to the extent of about 80 *per cent.*

The residue, 20 *per cent.*, was found not to be hydrogen; so it may safely be said that *the whole of the hydrogen had disappeared,* the plant remaining perfectly healthy. I can only explain this phenomenon by assuming that the nascent oxygen emitted by the leaves burns up the hydrogen, and converts it into water. The same thing occurred with the *Antirrhinum*, but the action was slower. In both cases the leaves were slightly bleached, and as the water charged with carbonic acid rose in the apparatus and covered them, they became green again.

In all these experiments the plants were exposed to the constant light of a northern sky, such as artists use for painting.

The rapidity of cell formation in an atmosphere of hydrogen gas, observed in the case of *Convolvulus arvensis*, was highly remarkable.

CHAPTER IV.

The Discoveries made by Priestley—Mutual Dependency of Animals and Plants—The Author's Experiments with Unicellular *Algæ*—The Author's Experiments with *Convolvulus arvensis* and other Plants.

In 1791, when Dr. Priestley's house was burnt by the Birmingham mob, and he saved his life by escaping in my grandfather's carriage, a considerable amount of valuable silver plate, etc., was carried off, but none of the still more valuable MSS., the results of years of labour. These were destroyed, together with the entire library and laboratory. It is therefore impossible to say how far he may have pushed his investigations with regard to the mutual dependency of plants and animals after discovering, some twenty years previously, that "a sprig of mint vegetating for a few days in an air vitiated by a burning candle restored the purity of that air sufficiently to allow the candle to burn in it again."

In the seventh edition of the *Introduction to Botany*, by Sir J. E. Smith, edited by William Hooker (1803, page 104), the author, alluding to the absorption of carbonic acid by plants, and its replacement, volume

for volume, by oxygen gas, says: "This beautiful discovery, for the main principles of which we are indebted to the celebrated Dr. Priestley, shows *a mutual dependence* of the animal and vegetable kingdoms on each other, which had never been suspected before his time."

It is not probable, however, that Priestley could have made much further advance in this direction, owing to the backward state of chemistry in his day, and to his zeal for political and religious discussions. It was reserved for the persevering researches of the Swiss chemist, Théodore de Saussure, and to the splendid genius of Justus von Liebig, to demonstrate this mutual dependency in all its striking realities.

Yet it is greater than even Liebig imagined!

After having found that minute microscopic plants, such as the *Protococcus pluvialis* and *P. palustris* (unicellular algæ), could be easily transformed, so to speak, into manufacturers of oxygen gas,[1] and that they produced it more rapidly than do the higher plants of our epoch, I placed several kinds of the latter in pure carbonic acid, and found that it did not kill them at once, as it would kill an animal, but that they lived in it for some time, though they did not prosper. In an atmosphere of hydrogen they lived and prospered; but the hydrogen gas was slowly absorbed, as we have already seen, until it had all disappeared. In the next place I exposed my plants to an atmosphere of pure

[1] Phipson, "Production of Oxygen by *Protococcus pluvialis*" (with figure of the apparatus), *Chemical News*, 1883; "The free Oxygen of the Atmosphere," *ibid.*, November 1894.

nitrogen, and to what I may term a "primitive atmosphere," consisting chiefly of nitrogen, with some carbonic acid and vapour of water, and I found that, in both cases, vegetation was remarkably healthy, and even luxuriant, for a lengthened period.

A small plant of *Convolvulus arvensis*, having its roots in the soil, or in water containing ample carbonic acid and mineral ingredients, vegetated in an atmosphere of pure nitrogen for ten days (22nd June to 2nd July). I then let in carbonic acid, an equal volume, which in twenty-four hours was absorbed by the water to the extent of about one-half; so that the artificial atmosphere, on the next day, consisted of about three volumes of nitrogen and one volume of carbonic acid. In this atmosphere the vegetation became truly luxuriant from the 2nd to the 15th July, and would doubtless have continued much longer had not the experiment been stopped in order to analyse the gas, and because the plant had reached the summit of the apparatus, and was pressing against the glass.

In another similar experiment the residual gas, *after fourteen weeks of vegetation, was found to be richer in oxygen than ordinary atmospheric air.*[1]

In these experiments the plant appears to absorb carbonic acid by the roots (as well as the leaves), whilst it evolves oxygen by the leaves; so that, after awhile, the nitrogen atmosphere contains a certain quantity of oxygen and, in time, approaches, or even surpasses, the composition of ordinary air.

[1] See APPENDIX for fuller account of this experiment.

CHAPTER V.

Attempts to Define the Primitive Conditions of the Globe from the Results of Modern Research—The Dawn of Animal Life—Effects of the Gradual Increase of Atmospheric Oxygen.

Now, if I endeavour in thought to go back to the primitive ages of the globe, I find that there was probably a period at which the heat was so intense that no compounds could exist. The matter of the Earth then existed in the state of free elements, or, according to my own theory,[1] in the state of *atoms all identical.*

As the temperature decreased, compounds of all kinds were formed according to the laws of affinity; and, finally, there remained, surrounding the solidified surface of the Earth, an *atmosphere of nitrogen*—a substance which is known to have no tendency to combine directly with other substances.

That there was *no free oxygen* in this primitive atmosphere is evident from the presence of various oxidizable substances in the primitive rocks of our globe. It is *into this primitive atmosphere of nitrogen that plants have poured oxygen, year after year, for countless myriads of*

[1] Phipson, *Outlines of a New Atomic Theory*, fourth edition, London, 1886. See APPENDIX.

ages, until it has attained the composition which it has at the present day.

In remote geological periods it may have contained much more carbonic acid than at present; but carbonic acid could never have predominated, from the fact that it would have been absorbed by the waters of the oceans, lakes, and rivers, and from my experiments, which show that even our modern plants can live in an atmosphere of nitrogen, but do not thrive in pure carbonic acid.

I was thus led to the conclusion that the *original atmosphere of our globe* consisted of *nitrogen* alone, and that the *oxygen of the atmosphere* is the *product of vegetable life* (which must necessarily have preceded animal life).[1] The production of oxygen by the minute unicellular algæ exposed to the light of the sun is a symbol of what took place in the primitive ages of the Earth. Carbonic acid must be looked upon as a volcanic product, extensively diffused through the Earth's strata, and into the atmosphere and waters. The primitive atmosphere of nitrogen would derive abundance of carbonic acid and vapour from volcanic action, which continued to be very intense long after the Coal flora period, and appears to have gradually diminished from that period to the present time, though it is still very active in many parts of the globe.

Now let me say a few words on the *dawn of animal life.*

[1] It might be objected that the plants which first produced atmospheric oxygen must already have contained oxygen as part of their tissues. Whence did they derive that oxygen? But I have never said that plants were the creators of oxygen, only that they were *the means by which Nature has placed free oxygen in the atmosphere of the Earth.*

I have endeavoured to show that in the earliest ages of the Earth, when life first made its appearance, plants (*anaërobics*) must have been formed long before animals (*aërobics*), since free oxygen was absent from the primitive atmosphere. My experiments on vegetation in hydrogen show that free hydrogen could not have existed in this primitive atmosphere any more than it can exist for any length of time in the atmospheric air of our days, without becoming oxidized, and converted into water.

Nitrogen alone, on account of its inert nature, could have formed the Earth's atmosphere in the earliest ages of our planet's history; and previous to the advent of life, this primitive atmosphere was charged with carbonic acid and vapour of water by volcanic action, such as we see manifested to a considerable extent at the present time.

Hence, the earlier vegetative life of the globe developed in an atmosphere devoid of free oxygen, consisting of nitrogen gas, with a certain admixture of carbonic acid and vapour, *the whole of the oxygen now present in the air being due entirely to vegetation extending over immense periods of time.*

As the ancient plants were evidently anaërobic, it was very interesting to ascertain whether the plants of our present epoch were essentially of the same nature; and my experiments have shown me that they are; also, that they must have preceded animal life.

Animal life has resulted naturally from the gradual transformation of anaërobic cells into aërobic cells, as a

consequence of the changing conditions, that is, *the oxygen constantly poured into the air by vegetation.*

At what precise geological period oxygen became present in sufficient quantity to allow of animal life might appear an extremely interesting problem to solve; but *no such period will ever be determined,* because the change must have been exceedingly gradual, and the study of the lower forms of plant and animal life show us that there is no hard and fast line between the two kingdoms. There is no such thing to be discovered as "the first vestiges of animal life."

As the oxygen evolved from the anaërobic cells became slowly and gradually a greater factor in the composition of the air, these cells had to accustom themselves to it, until some became more or less aërobic, and, finally, entirely so, and by their vital functions actually supplied carbonic acid to the air instead of oxygen.

Between green plants, beings which are essentially *anaërobic*, and the more perfect animals, beings which are just as essentially *aërobic*, there exists a vast intermediate class which presents, more or less, the characteristics of both; such are the various organized ferments, fungi and bacteria, etc., which represent the gradual transformation of the anaërobic cell into the aërobic cell, under the influence of the gradual change of medium; that is, the constantly-increasing amount of free oxygen in the atmosphere since the earlier geological ages. In the common yeast-fungus we have a familiar example of a cell which has undergone the influence of

the change referred to—*a cell which combines the plant and animal properties*, and secretes carbonic acid in the conditions in which the green unicellular algæ secrete oxygen. In the latter case, the oxygen evolved is separated from carbonic acid, and the carbon retained by the plant; in the former, carbonic acid is secreted by the yeast cell just as in the higher animals; the function is far more complicated, and requires a special nutriment, and the existence is rapid and short.

The French naturalist, A. Dissard, has recently published a paper, *La transpiration et la respiration chez les Batraciens* (*Comptes-rendus*, Paris), which gives us some idea how the change in the medium determines a change of function, such as I allude to here. Respiration is more active with aërial batrachians than in the aquatic species; exactly the reverse occurs for transpiration.

In one of my experiments, in which a *Convolvulus* grew for fourteen weeks (25th July to 30th October 1893), the confined "primitive atmosphere" lost all its carbonic acid, and the atmosphere at the end of the experiment was richer in oxygen than is ordinary atmospheric air. This shows what would happen to the Earth's atmosphere if there were an excessive supply of carbonic acid, and vegetation did not deteriorate: *the oxygen of the air would increase year by year.*

In the present state of things there is a kind of equilibrium apparent (not real), as during the last fifty or sixty years no great excess of oxygen gas has been detected by chemical analysis of the air, in whatever

locality, or at whatever elevation over the sea it may happen to have been collected. But what are fifty or sixty years compared to the thousands of centuries by which Nature counts her periods!

At Palermo it has been found that there is a slight diminution of oxygen in the air whilst the *Sirocco* blows. At Dresden, Professor Ficinus found a slight variation according to the direction of the wind; with the west and south winds the quantity of oxygen was always the highest. Something similar has been noted with regard to air analyzed at Copenhagen, at Helsingfors, at Guadaloupe, and of the air over the North Sea. In spite of the utmost care in the analyses, there were considerable differences in the amount of oxygen found in all these cases. The air of Calcutta during an outbreak of Cholera in 1845 yielded only 20·35 of oxygen (instead of 21), and 0·13 of carbonic acid (instead of 0·04 or 0·05); and there are other examples tending to show that the volumetric proportion of 79 of nitrogen to 21 of oxygen is anything but a fixed quantity. However, I have little faith in the accuracy of these analyses; and they must always be reduced to 0° C. and 30 inches barometer, which some of them were not. In former years also, analysis of the air was very frequently performed with phosphorus, which gives extremely erroneous results unless special precautions are taken.

In concluding the first part of this little work, we cannot help observing that it is a striking reflection when we consider that all the superiority of Man upon

this Earth depends upon fire, and that this fire is got by oxygen, originally the product of the minute cells of such humble plants as the microscopic unicellular algæ, vegetating under the mysterious agency of the Sun's rays!

Light, indeed, may be said to be the origin of Life.

PART II.

THE ATMOSPHERE OF OUR PRESENT PERIOD.

CHAPTER VI.

The Atmosphere is only a Mixture of Gases, not a Compound—Irrefragable Proof of this by Berzélius—Its Changeable Composition—The Inert Nature of Nitrogen—Ammonia and Nitric Acid—The Author's Experiments on their Mutual Conversion—The Unexplained Phenomenon of "Nitrification"—Its Universality—Ammonia, like Carbonic Acid, a Volcanic Product—Nitrification due to the Oxidation of Atmospheric Ammonia.

THE ancients looked upon the air as an element, and I have shown that in the earliest ages of the globe it was really so, for the atmosphere must then have consisted of nitrogen only, and the free oxygen which now forms part of the air we breathe, and without which animal life is impossible, is entirely the product of plant life extending over countless ages.

At the present time the atmosphere of the Earth, in accordance with the foregoing considerations, is not a compound, but a *mixture* of nitrogen and oxygen. This was amply proved by the great Swedish chemist, Berzélius, in his *Traité de Chimie* (vol. i. p. 88, Belgian

edition). Here is the passage in question; it constitutes an important page in the history of science:—

"Some naturalists have endeavoured to prove that atmospheric air is an *oxide of nitrogen.* They base their opinion chiefly on the fact that it is almost exactly composed of four parts of nitrogen for one part of oxygen, and that consequently it contains half as much oxygen as nitric oxide gas. But if such were the case, atmospheric air would offer to us the first known example of a simple mixture having absolutely the same properties as a chemical combination of the same elements. For, in fact, an artificial mixture of four parts of nitrogen and one of oxygen does not differ from atmospheric air as to its physical and chemical properties; and what proves clearly that this mixture is not a chemical compound is that no change in the volume, nor of the temperature, takes place at the moment the mixture is made. As, moreover, nitric oxide gas is converted into nitrous acid when it comes in contact with the air, it would result from this opinion that an oxide of a higher degree, and containing more oxygen, would possess the property of reducing, without the co-operation of any third body, an inferior degree of oxidation of the same radicle, a case of which Chemistry offers no example. Atmospheric air is, therefore, not a gaseous oxide of nitrogen, but *a simple mixture of nitrogen and oxygen gases.*"

This settled the question for ever. And it was this knowledge that our atmosphere is but a *mixture*, and

not a compound, that has hitherto been an enigma in Science, ever since the fact was discovered.

The more so that, neglecting to take into account that "time is the creation of Man," it was judged from a few analyses extending over a small number of years, that the proportion of oxygen and nitrogen in the air is invariable, and never has varied!

If only a mixture, and not a definite compound, how is it, people ask, that its composition remains fixed?—how is it that it shows the same quantities of oxygen and nitrogen in whatever part of the Earth it is analyzed, and at whatever height above the sea the sample of air is taken?

All this is explained, of course, by allusion to the law of diffusion of gases. But it must not be forgotten that changes in nature are very gradual, and very slow in comparison with the short, rapid span of Man's existence.

Several eminent men have already supposed, as we have seen, that the composition of the atmosphere is changeable. A slight practical glimpse of such a fact occurred in the analyses made by Levy, a Danish chemist, of air lying over the waters of the ocean between Havre and Copenhagen; and I myself made similar experiments with air taken at the surface of the sea many miles from the coast of Flanders. Such air contains somewhat less oxygen than that which is collected on the land. This was explained by the fact that oxygen gas is slightly more soluble in water than is nitrogen; and free oxygen is required for the respiration of aquatic animals.

The same slight deficiency of oxygen should be found in air lying over vast inland lakes; for, the air extracted from fresh water, by boiling, contains 33 *per cent.* of oxygen, instead of 21 (the proportion in atmospheric air). But the constant motion of the air keeps its composition very similar in all its parts, like that of a solution of sugar constantly stirred by a glass rod.

Then, the nature of Nitrogen formed a subject of uncertainty. Here is a substance which, combined with oxygen, forms one of the strongest *acids*, and, combined with hydrogen, one of the most powerful *alkalies.*

Now, other substances combine both with oxygen and hydrogen, but, as Berzélius remarks, always to form acids (*Traité de Chimie*, vol. i. p. 146, Belgian edition). It is true that phosphorus and arsenic imitate nitrogen in this respect, but they form nothing comparable for energy with *nitric acid* and *ammonia.*

Berzélius did not perceive that nitrogen is essentially *neutral*, or inert; that is why it must have formed *the original atmosphere of the Earth.* Hence, in nitric acid all the electro-negative properties of oxygen are apparent, and in ammonia all the electro-positive properties of hydrogen. In neither case does the neutral nitrogen interfere. It is *the only element of this absolutely neutral nature.* Hence, also, all the compounds of nitrogen have to be formed indirectly, by roundabout processes.

We have no facts in the whole range of Chemistry more striking than that the two substances *ammonia*

and *nitric acid*, so essentially opposite in character, are readily convertible one into the other. I have found, for instance, that ammonia oxidized in the cold by a solution of permanganate of potash, forms nitrite and nitrate of potash; and it has long been known that when zinc, or tin, is dissolved in nitric acid ammonia is found in the solution.

For many years it has been supposed that the nitrogen of the atmosphere plays an important part in the process of "nitrification," and many theories have been put forth to explain it—porous bodies, catalysis, electricity, bacteria, etc.—but we may safely assert that it is still unexplained.

In several experiments I made, years ago, with the view of thus forming saltpetre artificially, *I never obtained any nitrates unless some ammonia-yielding substance was present*, and I look upon the phenomenon of *nitrification* as due to the slow *oxidation of ammonia* in nature. The process is universal; it occurs constantly, everywhere; but it is only in those parts of the globe where rain is scarce that the resultant nitrates are easily discovered, or where they *effloresce* from the soil. In all other places they are washed away by the rain as fast as they are produced, and find their way into the rivers.

Now, ammonia is not only a *volcanic product* (like carbonic acid), but an *organic residue*—a secretion that has found its way into the superficial strata of the Earth ever since life appeared upon the globe. Ammonia is a poison to plants, but nitrates are absorbed by all

vegetables, and I have convinced myself that *ammonia is converted into nitric acid* before its nitrogen can enter the plant, and that *ammonia will kill the plant unless this conversion can take place.*

In the earlier ages of the globe, there could have been no nitric acid, nor even ammonia; but when the Earth had cooled sufficiently—long before life appeared—ammonia could exist in the volcanic products as it does at the present day, but no nitric acid.[1] Later still, nitric acid formed from ammonia ("nitrification") was produced, and plant-life became possible.

Ammonia, like carbonic acid, must therefore be looked upon as a volcanic product; and, when organized beings decay, their nitrogen and carbon return to nature as ammonia and carbonic acid.

Hence it is evident that atmospheric nitrogen takes no part in the important process of nitrification, unless it be that which is directly converted into nitric acid during combustion of various substances in the air, or by the lightning flash, and which may, after all, be due to the ammonia that is *always* present in the air.

[1] Ammonia has recently been found in the mineral Apophyllite, to the extent of 0·03 to 0·5 per cent.

CHAPTER VII.

Definition of the Atmosphere of the Present Day—Transparency—Spectral Lines of Oxygen not given by the Sun's Atmosphere—Observations and Experiments of Janssen, Piazzi-Smyth, Langley, Dewar, and Faraday.

A POPULAR writer on Science has said: "The Earth we inhabit is surrounded by an atmosphere of air, the height of which is known to be at least forty-five miles. It presses upon the Earth with a weight equal, at the level of the sea, to about 15 lbs. on every square inch of surface. As we ascend high mountains, this weight becomes less; as we go down into deep mines, it becomes sensibly greater. We breathe this atmospheric air, and without it we could not live many moments. It floats around the Earth, being in perpetual motion; and according to the swiftness with which it moves, it produces gentle breezes, high winds, or terrible tornadoes."

It is hardly possible to give, in fewer words, a general definition of the Earth's atmosphere.

The transparency of the air, *cæteris paribus*, must increase with the height above the Sea; but this increased transparency shows itself in a very remark-

able manner: the absence of some of the *spectral lines of oxygen*, when the Sun is viewed from the summit of Mont Blanc, has recently led the well-known French astronomer, M. Janssen, to the conclusion that *there is probably no oxygen in the Sun's atmosphere.*

My friend, Piazzi-Smyth, when Astronomer-Royal for Scotland, was the first, many years ago, to carry an astronomical telescope into the higher regions of the atmosphere. With the view of avoiding the influence of a dense layer of air, he took his instrument to the top of the Peak of Teneriffe, where he made some very interesting physical and astronomical observations. These were, on his return to England, the occasion of the publication of one of the most curious and delightful books in our language (*An Astronomer's Experiment*, etc.).

Since then, we have had a number of similar observations by Professor S. P. Langley, of Washington, which have been carried out on the heights of the Californian mountains, in one of the districts of the globe where the atmosphere is extremely pure, and where he was provided with one of the finest telescopes ever constructed. Under these most advantageous circumstances, Mr. Langley made observations on the heat and colour of the sun and planets, the distribution of the lines of the spectrum, the constitution of the solar surface, the distribution of light and heat upon the disc, the extent of the absorbing power of the Sun's atmosphere, and that of our Earth, the temperature of the Sun (which he fixes at some degrees higher than

the fusion point of platinum), and many other important researches, to which we need not here refer.

I should mention, also, the recent curious experiments made by Professor Dewar, of the Royal Institution, on the *liquefaction of oxygen gas and of atmospheric air*, accomplished by the application of intense cold and pressure. In following up the experiments of Pictet and others in this direction, our English professor has gone a step further (*Chemical News*, 19th January 1894), and his results have excited general interest. Berzélius recognized that *the true colour of atmospheric air* is blue, and the liquefied oxygen of Professor Dewar is likewise blue. It possesses the most singular properties, being without any action upon such inflammable metals as potassium and sodium, which shows what an enormous influence is exerted by *temperature* on chemical action. This became evident, years ago, in experiments by the celebrated Faraday[1] as regards liquefied gases. He found that liquefied protoxide of nitrogen would not act on potassium, nor liquefied chlorine on antimony, etc.

[1] See Dumas, *Éloge de Faraday*, p. 12.

CHAPTER VIII.

Sulphur always present in the Atmosphere—Characin, the Cause of the Odour of Marshy Air—Odours of the Air in Different Countries—The Odour of the Sea-Air—Detected by the Author in Marine Fossils of the Tertiary Period—Odour of the Air after a Summer Shower—Observations regarding Ozone.

PURE air is odourless and tasteless, except when *ozone* is strongly developed, or when lightning strikes an object on the surface of the Earth. In the latter case, an odour of *sulphurous acid* is distinctly noticed, as I have had occasion to observe more than once. On one of these occasions, in Paris in 1858, it affected the neighbourhood for a considerable distance around, and penetrated all the houses.

This odour of sulphurous acid is likewise perceived at sea when a ship is struck by lightning. It proves the existence of a certain amount of sulphur, or some compound of sulphur, in the air, even hundreds of miles from land.

That sulphur, in some form, is a constant constituent of the Earth's atmosphere appears to be becoming less doubtful every day. In the early part of this century a writer in the *Archiven der Pharmacie*, named Dulk,

reported that after a storm of thunder and lightning which broke over Osterrode, in Prussia, on the 22nd April 1836, a yellow powder was found in the water collected from two streams. It was formed of coarse grains, *like small hailstones*, some of which were nearly as large as peas, and these formed semi-transparent drops, which were fragile, and could be easily broken between the fingers. Afterwards, the grains became a darker yellow, and harder; so that they could no longer be broken by pressure between the fingers. It was *proved that these yellow grains were sulphur*, much purer than the ordinary brimstone of trade. Mr. Dulk, and his friend Mr. Lange, then requested the Mayor of Osterrode to enquire of the proprietors of the streams what had happened. The latter, and their servants, all declared that there had been *no sulphur before the storm*, and that after the storm, sulphur had not only been found in the two streams, but in the gutters, and empty vessels, such as saucepans and tubs, belonging to artisans in the neighbourhood.

The so-called "sulphur rain" due to the pollen of the Pine trees, often observed in Norway and Sweden, has been occasionally witnessed also at Oleron in the Basses Pyrénées (France).

Another cause of odour in the air, extending over wide districts of marshy lands, is due to the volatile substance *characin*, which I discovered in 1879.[1] It forms very thin iridescent films on the surface of stagnant waters where algæ abound, and on the water of

[1] *Chemical News*, London, 1879.

tanks in which these microscopic plants are cultivated. It is soluble in alcohol and ether, and is volatile, it possesses the characteristic odour of marshy air, so intense during hot summer weather in the flat districts of Flanders, especially along the wide ditches which border the *Chaussées*, where I first noticed it. It has the odour of the *Chara*, hence the name I gave it, and to most persons is very disagreeable (botanists call one of the species *Chara fœtida*); but all fresh water *Algæ* produce it, *Conferva*, *Palmella*, *Oscillaria*, etc.; and it is often to be noticed, during hot weather, in glass tumblers which have been wiped out with a towel on which microscopic *Algæ* have developed, through want of cleanliness, and neglect of soaking the glass-towels in boiling water. Characin may, of course, be produced by the influence of microbes, but it is quite distinct from them, being a well-defined substance, approaching to the nature of camphor.

I have noticed, during my travels in Europe, that on passing from one country to another, a different odour is perceptible in the atmosphere. If we take the boat to Ostend, for instance, we are at once struck, on arriving, by the peculiar odour in the air; and the traveller who proceeds from Belgium to France, from France to Germany, etc., can scarcely fail to notice the peculiar change in the odour of the air when he changes his abode to reside in another country. The cause of this must be looked for in the various modes of life of the inhabitants, and has little to do with the natural constituents of the atmosphere. But even a journey

from an inland region to the sea-coast makes us aware of what is commonly called the "odour of the sea," which was noticed as early as the days of Alexander the Great; for the old author, Quintus Curtius Rufus, distinctly informs us that the soldiers of Alexander knew when they approached the sea by the odour it diffused in the air—"*agnoscere se auram maris.*"

Now, I have found that the fossil marine worms (*Teredo*), which I used often to obtain from the *tertiary* sands of Brussels, gave a distinct odour of the sea (*aura maris*), when broken with a hammer, or scratched with a knife, shortly after being taken from the strata in which they have been imbedded for *myriads of centuries.*[1] This is infinitely more astonishing than the accounts of the extraordinary persistency of the odour of a grain of musk diffused through the atmosphere of a large room for a great number of years.

Travelling on foot in Germany, I was often able, during the night as well as by day, to distinguish when I was approaching a beech forest or a pine forest, by the different odour diffused through the air by each of these trees.

All these facts show that the lower regions of the air become impregnated with various volatile substances which are constantly produced on the Earth's surface, and the most minute quantities of which affect the delicate tissue of the sensitive olfactive nerves. I need

[1] Phipson, "Note sur les Térédo fossiles," in the *Comptes-rendus* of tho Paris Academy of Sciences, 1857.

not develop this subject further; but there is one observation I desire particularly to allude to, namely, the very delicious odour perceived in the air of a country garden after a heavy summer shower. For many years the cause of this odour escaped me completely until, one day in 1863, I found that certain specimens of chalk taken in the open country of Picardy, in France, developed a similar fragrance when they were dissolved in diluted hydrochloric acid. For a long time I was unable to trap the odoriferous substance which thus escaped with the carbonic acid; but finally I succeeded by passing the gas given off by the chalk through a solution of bromine in water. The bromine compound thus obtained was found to be analogous to *bromo-cedren,* showing that the odour was due to some essence like that of cedar. Hence, I was led to conclude that the pleasant fragrance diffused through the air in a country flower-garden after a heavy shower of rain, is due to the displacement by the rain of the flower-essences (essential oils) absorbed by the dry porous soil during the hot days of summer. Many years afterwards a well-known chemist in Paris made some experiments, which fully confirmed my views in this respect (*Chem. News,* Lond. 1891).

So much has been written upon the peculiar state of oxygen known as *ozone,* that my remarks on this subject must be very brief.[1] With us in England, I find it

[1] Phipson, "La Force Catalytique," etc. (*Soc. Holl. des Sc.*, Haarlem, 1858). See also the same author's papers in the *Chemical News*, London, from 1860 to the present time.

occurs chiefly with westerly winds blowing direct from the Atlantic, and is very perceptible on going into the open air after being for some time in the close atmosphere of a room. Those who wish to know what this odour in the atmosphere is like, should place a stick of phosphorus in some water contained in a large glass globe, in such a manner that about half the phosphorus stands above the water. In the course of a few hours the air of the glass globe will have a very strong odour of ozone, and will act upon a strip of paper steeped in starch with a little iodide of potassium, turning it blue.

The presence of ozone in the atmosphere of any given locality renders the air highly tonic, bracing, and antiseptic. It is rarely present in the atmosphere of densely populated districts, except when a westerly gale is blowing, as it is readily destroyed by the effluvia of animal life, and in presence of organic matter prone to oxidation, or in a state of decay. It is often present in sea-air. Some experiments which I published long ago (*loc. cit.*) have proved that whenever the atmosphere acts upon an organic substance, such for instance as a slice of apple, which it turns brown, the oxygen is immediately transformed into ozone (called by some "nascent oxygen," because when oxygen leaves a compound it is in the same state).

Again, ozone formed in an atmosphere at a very low temperature such as is met with in the Arctic regions, is liable to affect the flesh of animals exposed to it before being cooked, inducing all the effects of putre-

faction, as was observed by the young and ardent explorer Dr. Kane in the famous Grinnell Expedition in search of Sir John Franklin.[1]

[1] Phipson, "Sur la putréfaction à 35° sous zéro," in the *Comptes-rendus* of the Paris Academy, 1859.

CHAPTER IX.

The Electric Phenomena of the Atmosphere—The Author's Researches and History of Electric Discoveries—Phosphorescence of the Air—Vibratory Nature of the Lightning-flash.

THE electric phenomena of the atmosphere have always been a source of the greatest interest, and the discovery of the nature of lightning by Benjamin Franklin was one of the greatest achievements of the last century. A history of Atmospheric Electricity is given in one of my former works,[1] where I have traced the progress of this important branch of physical science from its birth to the present epoch, giving an account of Franklin's celebrated kite experiment and what led up to it. Long electric sparks had been obtained from the extremities of isolated metallic rods, raised high in the air, by Dalibard in France, some months before Franklin made his experiment; but it was at the suggestion of the latter. Such experiments are very dangerous, and the young Professor Richmann was killed in this way at St. Petersburg.

It is not necessary that storm-clouds should be present, for if an isolated condenser be suddenly

[1] *Familiar Letters on some Mysteries of Nature*, London, 1876.

launched into the air at any time, strong currents of electricity (usually *positive*) are obtained. This experiment, which I performed for the first time in company with William Thomson (now Lord Kelvin), many years ago, at the Philosophical Institution in Glasgow, was merely an extension of the ingenious experiments of Bénédict de Saussure (1767), made in the Alps with his electroscope:[1] whenever he raised the little instrument above his head, the pith-balls separated, showing that the electric tension of the atmosphere increases with the height above the ground, and is generally *positive.*

M. Ch. André[2] concludes from observations, made in a balloon, on the variation of the electric state of the higher regions of the air, that *in fine weather* the electric tension certainly does *not* increase with the altitude; but he does not appear to be entirely satisfied, at present, with these observations, and hopes to repeat them.

During a thunderstorm, this tension will change its sign many times, often, in fact, with every flash of lightning. In the experiment just alluded to, the isolated condenser, communicating by a long wire with Thomson's galvanometer-electroscope upon the table, was attached to a long pole: when this was thrust suddenly out of a window to a great height in the air, the needle of the galvanometer was immediately set in violent motion.

[1] Bénédict de Saussure, *Voyages dans les Alpes*, 4 vols., 1779–1796.

[2] Ch. André in the *Comptes-rendus* of the Paris Academy, 27th November 1893.

In recent times Mr. M'Adie has succeeded in getting electric sparks from a kite raised in the air *when there were no clouds in the sky.*

In August 1894, four soldiers were struck down, and severely injured, in presence of the Duke and Duchess of Connaught, at Aldershot, by a flash of lightning that destroyed a captive balloon to which they were attending. The day was characterized by a series of small thunder-showers of short duration.

In dry summer weather, the dust raised by the French postilions in Languedoc, during the afternoon, has been known to remain suspended in the air the whole of the night, on account of its electric state. That this electricity is due to the *friction* of the horses' feet, may be demonstrated by throwing a little fine dry sand upon the condenser of a galvanometer-electroscope, and blowing it off again; in each case the needle of the instrument is vividly deflected.

I have described, in my work above mentioned, a number of wonderful phenomena due to atmospheric electricity, such as the emission of light from the hats, and raised hands, of travellers on the summit of a mountain, the buzzing noise emitted by their Alpen-stocks when thrust into the soil, which has been compared to that of a boiling kettle; the marvellous *field-lightning* of the Jura which, during electric disturbance of the air, plays over the pastures on the slopes of the mountains, and has also been witnessed in Mongolia. There, also, I have recorded the history of the discovery of lightning conductors by Benjamin Franklin (1749–

1752), and the discovery, a few years afterwards, by Thomas Ronayne, of London, concerning the *electric nature of fogs* (1761), a subject since investigated by Peltier and others.

An electrometer thrust into a dense London fog often shows enough electricity to send a telegram round the globe; and, in 1876, I published the following lines:—"If after ascertaining the nature (or sign) of this electricity, the fog could be supplied with a plentiful amount of opposite electricity, I have no doubt that it would be entirely dispersed in the course of a short time."[1]

Independently of the beautiful phenomena produced by the *Aurora borealis* in the highly rarefied regions of the atmosphere, I should notice here those gleams and flashes of light, probably of an electric nature, which I witnessed accompanying the remarkable swarm of shooting stars in November 13–14, 1866, and which were noticed by others in the star-shower seen the following year in the West Indies. An account of this phenomenon was given in my note to the Academy of Sciences at Paris in 1868.[2]

The *phosphorescence* of the air, which allows a traveller on the darkest nights, when there is no moon above the horizon, to find his way in the open country, and the phosphoric shining of isolated masses of cloud, often noticed, and described in my little

[1] Phipson, *Familiar Letters*, etc., p. 37.

[2] "Sur les phenomènes lumineux qui accompagnent les éssaims d'étoiles filantes" (in the *Comptes-rendus*, Paris, 1868).

volume on *Phosphorescence* published in 1862 (my first work in the English language), must doubtless, as Humboldt suggested, be connected with the *constantly varying electric state of the higher regions of the Earth's atmosphere.* These phenomena, which were known to the Italian philosopher, Beccaria, in the middle of the eighteenth century, have been often witnessed by me.

I should also mention the phosphorescence of the snow and ice on the glaciers of the Alps: the darker the night the more brilliant is this effect, so that it appears sometimes like a second sunset. The snow which lies in the valleys of Piedmont, Switzerland, Valais, etc., is likewise affected in the same way; the bluish light emitted in these cases is due to *phosphorescence by insolation.* It is not remarked on snow which has fallen shortly before night, and which, consequently, has not been long exposed to the sun.

Although Franklin and his successors have perfectly demonstrated the identity of lightning and the electric spark—suspected years before by Otto von Guericke and Dr. Watt—yet the exact *cause* of the light that flashes through the atmosphere, and of its tiny representative which rushes between the poles of an electric battery, is quite unknown. By modifying the medium, we modify the spark; so that in highly rarefied air, for instance, it takes the appearances of the *Aurora borealis.* What is the cause of the sudden light which issues from the storm-cloud, or through the air—how is that light produced?

Some writers have imagined that lightning was due to the combustion of hydrogen gas, supposed to exist in the higher regions of our atmosphere; or to that of carburetted hydrogen (marsh gas) which has really been detected on several occasions in the air; or, again, to that of nitrogen, as in the celebrated experiments of Cavendish, who obtained nitric acid by passing electric sparks through atmospheric air. Nitric acid is, indeed, present, in minute quantities, in storm rain, and I am of opinion that all rain likewise contains it.

My own idea is that lightning is due to a *vibration of the air* similar to what occurs in the little instrument known as the *briquet à air*, where sudden compression of the air in a cylinder by a blow upon the piston will cause it to ignite a piece of tinder. A similar vibration of the air is caused by the rupture of the extremity of a Prince Rupert drop, which causes a sudden light, and by the discharge of an air-gun, also by the rupture of a glass vessel exhausted of air.

Similar vibrations, producing light, occur when crystals form in liquids, or by cooling after fusion, or by sublimation, or when divided suddenly by cleavage—phenomena which I have witnessed scores of times.[1] So that *the minutest molecular vibration is capable of yielding a sudden flash of light.*

The close calm weather which often precedes thunder-

[1] Phipson, *Phosphorescence, or the Emission of Light by Minerals*, etc., 1 vol., London, 1862.

storms in our temperate climate, is accompanied by an increase in the various odours perceived in the air. The perfume of flowers is very much stronger for awhile; and, in country places, it is not unusual to perceive, at such times, the disagreeable odour of cess-pools all over the district—a fact which clearly points to the necessity of a more perfect system of drainage and disinfection in our country homes.

CHAPTER X.

An Unexplained Condition of the Atmosphere—Effects of Glare—Snow-blindness—Hemeralopia and Amaurosis.

There is a certain, hitherto unexplained, condition of the atmosphere, which usually lasts for a few hours at a time, and rarely more than one day, or, perhaps, two days. During this condition the optic nerves of men and animals are painfully affected. I allude to what is commonly called "glare," not unfrequently perceived at the seaside, and often when the sun is not shining brilliantly, but is hidden by thin cloud, or haze.

The existence of this painful "glare," even when the sun is dimmed, is a subject which has not been fully studied. I feel convinced that we have in the solar spectrum, besides the rays of *light* and *heat*, and the *actinic*, or chemical rays, others which specially affect the nervous system in the higher animals, and which appear to act also on those lower forms of life, in some of which no traces of a nervous system have, as yet, been discovered. This peculiar condition of the atmosphere affects some people more than others. Many are obliged to wear coloured glasses

in order to avoid its effects, or to pull down the brim of their felt hats to a level with the lower eyelids, as they do at Naples.

Snow-blindness is supposed to be occasioned by the vivid reflection of the solar light from the white mantle of the brilliant white crystals which covers the ground, and more or less complete amaurosis is produced, especially in aged persons, by the bright solar radiation on the sea-coast, or by the light from brilliant white houses in inland cities.

One of the most remarkable cases of snow-blindness ever reported is that by the late General Miller, in the *Edinburgh New Philosophical Journal* (1835): A division marching from Cuzco to Puno, in Peru, halted at Santa Rosa. During the night, snow fell abundantly, nevertheless the march was continued next day, when, with few exceptions, the whole of the soldiers were attacked with sore eyes, "due to a disease called by the natives *norumpi*. It produces almost total blindness for some time, and great pain. There is also delirium of a peculiar kind, and it is often fatal. The division in question lost one hundred men in fifteen hours from this affection. The disease generally lasts two days."

Dr. August Berlin, of Stockholm, has proposed a new theory for snow-blindness. He went on an expedition to Greenland in 1883, during which he had ample opportunities for observing it.

The geographical distribution of the affection closely follows the *isothermal lines* in the three continents

bordering on the North Pole; it comes further south in America and Asia than it does in Europe. It is also met with in very elevated regions, even under the tropics. In the temperate zone it occurs occasionally, but in a milder form. Its cause, according to Dr. Berlin, resides in *great dryness of the air, and intensity of the solar rays.*

To prevent snow-blindness the Esquimaux use a disk of thin wood with a minute transverse slit in the centre. They call these wooden spectacles their "snow-eyes." Instead of this, goggles made of moderately fine wire network, without glass, have been recommended.

Medical men class these atmospheric effects upon the optic nerve under the term of *hemeralopia* (or "night-blindness," because they are chiefly observed at night). It is not uncommon that a considerable number of soldiers become thus completely blind during the night, and recover their sight again at daybreak. The complaint comes on periodically every evening, and may last for a fortnight, or even for a whole month, when it disappears without leaving any traces.

The army surgeon, Dr. Hetter, saw sixty of his men struck down in this way at Wissembourg, just before the Franco-Prussian war; and the troops in garrison at Strassburg suffered in a similar manner. Generally speaking it is cured, in mild cases, by keeping the men in the dark for two or three hours; or, sometimes, for twelve hours. In 1891, Dr. Schirmer endeavoured to explain *this extraordinary atmospheric effect upon the*

eyes, by reporting it to an action upon the pigment-cells of the retina. But it *still remains a mystery.* That same year Dr. Venneman described an "epidemic" of hemeralopia which he observed in the neighbourhood of Louvain (Belgium). Forty-two cases of this peculiar affection came under his observation, and embraced all classes of people, children being more generally affected than adults. Fever, with headache, preceded the affection of the eyes, and lasted for two or three days. With the appearance of these symptoms the ophthalmoscope revealed a slight retinal œdema about the disc, especially along the course of the vessels, with diffuse streaks and markings of black pigment. When normal vision returned these appearances gradually vanished.

It is, therefore, an atmospheric effect upon the retina, or optic nerve; but no one has yet been able to determine *in what consists the special condition of our atmosphere which produces these curious and painful effects.* So little does the last-named physician suspect the real cause, that he looks upon the cases at Louvain as an epidemic, similar to influenza, confusing it with the amaurosis so often noticed, of late years, after attacks of that disease.

CHAPTER XI.

Solid Substances in the Atmosphere which fall upon the Earth, or can be detected in suspension in the Air—The Author's first Discovery of Iron Particles in the Air, after the Meteor Stream of November 1866—Confirmed by other Observers—His detection of Fossil Bacteria in the Air; and of minute Crystals of Ice—His Observation of Bundles of Grass transported for hundreds of miles—A Similar Case observed by Boussingault—Presence of Salt and Sulphate of Soda in the Air—Gossamer — Birds and Insects — Cosmic Dust — Explosion of Meteors — Periodic Plants — Transportation of Frogs, Stones, Volcanic Ash, etc.—List of Extraneous Substances — Mode of collecting Bacteria — Observations by Pasteur, Miguel, and the Author.

As early as 1854, I examined a singular mucilaginous substance mentioned by Mulder and Berzélius under the name of "*Mucilage atmosphérique.*" It is found lying in the low Flemish pasture lands in the neighbourhood of stagnant pools, and the peasants of the Netherlands believed it to be dropped by shooting-stars, since it is occasionally seen at night to be phosphorescent. I shall never forget the youthful ardour with which I went through the early morning mist in search of this mysterious atmospheric mucilage, trudging over the damp fields which surrounded my

father's house in the neighbourhood of Brussels, and scattering hundreds of large blue crows, which rose, on my approach, from the edges of the shallow patches of stagnant water. On careful examination it was found to be frog-spawn, which had been swallowed and then voided by the immense blue crows which are so numerous in those districts.

In connection with this curious subject I have since found that in Donovan's *British Birds* (1794, vol. iv., plate 77, the *Winter Gull*) he says: "Mr. Pennant observes that the gelatinous substance known by the name of *Star spot*, or *Star jelly*, owes its origin to this bird, or some of the kind, being nothing but the half-digested remains of earth-worms on which these birds feed, and often disgorge from their stomachs." The Winter Gull (*Larus hybernus*) is a common bird in England, and frequents inland rivers, fens, and moist meadows, hundreds of miles from the sea, in winter time; hence its name. Its general colour is white, with a few brown spots on the wings, etc.

Mr. Morton, in the *Natural History of Northamptonshire*, says: "In the course of my correspondence with J. Platt, of Oxford, I recollect his having mentioned that once meeting with a lump of this *Star jelly*, on examining it he found the toes of a frog or toad still adhering and undissolved, and from thence he concluded it to be the remains of one of these having been swallowed whole *by some bird*, and the indigestible parts brought up in the condition he found it."

About the same period, when prosecuting my studies

at the University of Brussels, I was called upon to make a chemical analysis of the *dust* collected by one of my professors from the air of houses in that city. I found that it consisted almost entirely of *organic matter*, leaving only a minute quantity of ash when burnt, in which *soda* appeared to be the principal ingredient.

Many years later, at the commencement of winter, I examined the *first fall of snow* in the neighbourhood of London, and found it teeming with *organic germs* and *unicellular Algæ*.

In 1866, shortly after the celebrated star-shower of November, described in one of my former works,[1] I exposed to a south-westerly gale, plates of glass covered with glycerine, which were afterwards examined under the microscope, and revealed some black specks which contained *iron*, and gave yellow chloride of iron by treatment with hydrochloric acid. This was *the first experiment of the kind ever made*, and is recorded in my book. Since then this observation has been confirmed by Cunningham, Tissandier, and others, who have all found *iron, probably of cosmic origin*, floating in the atmosphere of our Earth.

Ten years previously I had used the same device (with solution of gum instead of glycerine), both in France and in Belgium, for collecting substances carried through the air by the wind; and among other curious

[1] Phipson, *Meteors, Aërolites, and Falling Stars*, London, 1867. The description is an *Appendix*, as the work was written long before that famous star-shower occurred.

objects thus collected I have met with the microscopic hairs (*pili*) of certain Alpine plants, flourishing hundreds of miles from the spot where the experiment was made.

I have more recently collected in this manner extremely minute circular cells, which resisted a red heat in contact with the air, and were found to consist chiefly of silica. They appeared to be, in fact, *fossil bacteria*.[1]

It also fell to my lot, in my student days, to place beyond doubt the existence of *crystals of ice* in the atmosphere—minute crystals of ice suspended in the air, which are the cause of the phenomena known as Solar and Lunar *halos*: One night during the spring of 1855, a magnificent halo of 22 degrees encircled the moon as seen at Brussels. It is generally admitted that these halos portend "rain within twenty-four hours," which is explained by a change of wind—a warm southerly current mixing with the air in the higher regions charged with ice-crystals, and bringing down the latter as rain. On this particular occasion things occurred in a rather different manner; for, the following morning as I was proceeding to the University for the early Chemical Course at eight o'clock, I found the air full of minute floating crystals which glittered in the bright sunshine like myriads of small diamonds. It was a most curious sight, and one never to be forgotten. The tiny crystals fell all the morning, covering objects on

[1] Phipson, "Grains of Silica and Micrococci in the Atmosphere," published in the *Chemical News*, 1881.

the Earth's surface with a thin layer resembling hoar-frost, and finally changed to rain during the afternoon.

Here is another curious observation which I find among my notes. Standing one morning during the month of June 1861, on the banks of the River Thames, near London, I was a witness of the following singular spectacle:

The day was calm, with only a slight westerly breeze, there was bright sunshine, and the sky was blue. Suddenly there appeared moving specks in the atmosphere to the west of the spot on which I stood, and evidently at an enormous distance. They were like a very distant flight of birds; but they got much larger than any birds, as they approached. At last some of them began to fall into the river near Putney bridge; and two or three of these curious objects fell into my father's garden. On examination, they were found to be recently cut grass, twisted into circular masses, much larger than a man's head. I knew that no grass had been cut for hay within hundreds of miles of my residence, and I at once assimilated this phenomenon to the falling of volcanic ash upon ships far out at sea, and hundreds of miles from any volcanoes, of which instances have occasionally been put on record.

Many years afterwards, I found that a precisely similar phenomenon had been witnessed by the celebrated Boussingault at Caràcas, in Venezuela, and is mentioned in the second volume of Humboldt's *Views of Nature*.

M. Boussingault, who was then Professor at the

School of Mines at Santa-Fé de Bogota, whilst climbing the hills of Caràcas, witnessed in the middle of the day, during an excursion to the summit of Mount Silla, a phenomenon which appeared to prove in a striking manner the existence of *ascending currents of air*. He, and his companion, Don Mariano de Rivero, saw numbers of white, shining bodies rise from the Valley of Caràcas, and reach the summit of Mount Silla, 5400 feet high, whence they fell on the opposite slope. This phenomenon lasted for an entire hour, without any interruption. At first, M. Boussingault imagined it was a flight of birds, but he was soon able to convince himself that these bodies floating in the air were small, round bundles of grass, chiefly composed of the species *Aira tenacissima*, which is plentifully mixed with *Agrostis* grass of the valleys of Caràcas and Cumana.[1] The account of the phenomenon witnessed by me was published in the *Comptes-rendus* of the Paris Academy[2] before I knew of Boussingault's observation.

The presence of salt (*chloride of sodium*) in the air of the sea-coast, especially when a brisk breeze plays upon the spray of the waves, is a matter of common experience. But it is not so generally known that another sodium salt, namely, *sulphate of soda*, in the solid state, appears to be *constantly present in the atmosphere*, at least in the lower regions.

A supersaturated solution of sulphate of soda

[1] Humboldt, *Tableaux de la Nature*, vol. ii. p. 37.

[2] Phipson, "Sur une pluie de foin," in the *Comptes-rendus*, Paris, 1861.

crystallises immediately the bottle containing it is opened, in whatever place the observation may happen to be made, whilst solutions, equally saturated, of *other salts do not present the same phenomenon.*

This fact, which has been brought to light by F. Parmentier and M. Margueritte,[1] appears to prove most conclusively that *sulphate of soda must be constantly present in the lower regions of the atmosphere*, and this salt being universally suspended in the air, supplies the necessary microscopic nucleus-crystal, which causes the whole solution to solidify the moment the bottle is opened.

It has long been known that butterflies and other *insects* are occasionally transported, by aërial currents, from the valleys to the summits of the highest mountains, and far out to sea; and the *spiders' webs* which are found floating in the air (generally, with us, in October, though I have seen them also in March, both at St. Cloud, near Paris, and in the South of England), are alluded to by many of our poets as "gossamer." In this respect I shall never forget a journey I once made, in October, from Paris to Brussels, by the line then recently constructed through Erquelinnes. On alighting at the station of Erquelinnes, I noticed that the funnel of the engine was covered with these spiders' webs, and appeared just as if it had been wrapped in a silk shawl several inches thick. The description of the particular species of spider that migrates in this manner by the currents of the atmosphere is given by Kirby

[1] *Comptes-rendus* of the Paris Academy, 1889.

and Spence in their great work on Entomology. I have since seen it rise in the air, like a fly, from the summit of plants in my garden at Putney, in September, by means of its invisible thread.

Doubtless, the migration of birds is aided in a similar manner by currents of air. Our swallows usually appear in great numbers after a stiff gale has been blowing for many hours. It is difficult, however, to account for the manner in which the minute red spiders, known as *social mites*, are transported through the air. Suddenly, some fine morning, they will be found clustering by thousands, on nails, or other prominent objects, at the top of gates, or fencing, disappearing, in a few days, as mysteriously as they came. This singular occurrence has been sometimes witnessed in Putney and other westerly quarters of London.

In another place, I have given numerous instances of what is supposed to be *Cosmic dust*,[1] as distinguished from the better known dust, or ashes, due to volcanic eruptions, such as those of Krakatoa which, not very long ago, diffused into the atmosphere immense quantities of volcanic ash that remained suspended in the atmosphere for several years, producing the most gorgeous effects of sunset for two or three years in succession. It is very probable that fine sunsets of a less remarkable kind are often due to a similar cause.

The whole subject of Cosmic dust, and other sub-

[1] Phipson, *Meteors, Aërolites, and Falling Stars*, 1 vol., London, 1867.

stances observed to fall from the atmosphere, has been discussed in Chapters XIII. and XVII. of my work just alluded to. The late learned Baron von Reichenbach long ago collected virgin soil from the summits of mountains in Germany, and found it contained traces of *nickel*, a metal invariably present in aërolites. I did the same, in Waldeck, in 1865, taking the earth from places where human industry had not yet penetrated, and with similar results, which shows that *meteoric dust*, the produce of meteors, finds its way through the air to the surface of the Earth.

Professor Nordenskiold asserts that he has, also, collected meteoric dust in the snows and ice of the Arctic regions. But all these observations require more careful discussion than they have yet received, and so does that one published by Mr. Baumhauer, who found iron pyrites enclosed in hailstones which fell in Holland.[1]

The cause of the explosion of a meteor in the Earth's atmosphere is due to the *sudden rise of temperature on the surface* (which is thereby fused, whilst the interior is most intensely cold), by the friction with the air through which it rushes. It has been estimated that if the speed of a meteor is only slackened by $\frac{1}{100}$th, during its passage through the air, its temperature is raised on the surface to a much higher degree than that at which iron burns; and I have proved by actual experiment, that the *sudden* heating of the *surface* of a

[1] *Comptes-rendus*, 1872.

body intensely cold in its interior, as a meteor coming from cosmic space must be, is quite sufficient to explain the explosion and rupture of the aërolite.[1]

The great Italian naturalist, Spallanzani, has declared that he was never able to discover that curious plant, *Nostoc commune*, though he had often sought for it along garden walks, after showers of rain; and he thought botanists were mistaken in giving to it the specific name "*commune*." Now, I have noticed that the algæ of the *Nostoc* group appear abundantly in certain years and in certain places, without any apparent cause; and then disappear, apparently for ever, from these localities. The same singular phenomenon is found to occur with more highly organized plants; for instance, with the rare "bloody-finger grass" known to botanists as *Digitaria sanguinalis*, which appeared one year in my garden near London, though it is only to be found, now and then, as a great rarity, in the county of Norfolk. I could cite many other instances, not only of plants, but of animals, that pay us *periodic visits* in this manner. In 1893, the summer of which was unusually hot and dry, I found in my garden a species of wasp which inhabits the South of France, and is never seen in England; and I have found a dead African locust on the wild, deserted sandhills beyond Ostend, on the coast of Flanders.

All these facts are due, in the first instance, to accidental transportation by gales of wind, which carry

[1] Phipson, "Sur l'explosion et la chute des météores" in the *Comptes-rendus*, 1869.

germs of algæ, seeds of grasses, and other plants, etc., to immense distances, and they germinate and flourish wherever the conditions are favourable. These *conditions appear to be periodically favourable only*, for any given point of the globe; and when they cease to be so, the plant, or animal, disappears. It is a subject well worthy of more investigation than it has hitherto received.

Waterspouts have been known to carry *frogs* for many miles from marshy districts, and deposit them in large numbers in places where they were never seen before.

In 1864 I analysed[1] some *fragments of stone* that were carried through the air from the neighbourhood of Dudley to Birmingham, where they fell in the streets during a violent storm, and were supposed to be aërolites. My examination showed that they were really fragments of greenstone rock, known in the locality as "Rowley Rag" (the "rock of Rowley"—which forms a hill near the village of Rowley in Staffordshire).

Many old accounts of "rain of Sulphur" apply only to a fall of the yellow *pollen* of the northern pine trees, which is scattered by the wind; but there are well-authenticated cases of *real sulphur* falls, to one of which I have made special allusion on a preceding page. *Volcanic ash* of various colours—red, grey, and black—is not unfrequently brought down by the rain at great distances from its origin; and storm rains in

[1] *Brit. Assoc. Report*, 1864.

the West India islands often yield a large amount of *sea-salt*. The same thing occurs in other localities.

The principal *extraneous substances* which, according to my personal experience, appear to exist at almost all times in the atmosphere of the Earth, may be rapidly enumerated as follows:—

Water; *carbonic acid*; *sulphur*; *chloride of sodium*; *sulphate of soda*; *iron* (meteoric); *silica* (fossil bacteria, or micrococci); *desmids and foraminifera*; *spores of Algæ*; *unicellular Algæ* (always present in rain aud snow); *carbonaceous matter* of unknown nature; hairs (*pili*) of various plants; *débris* of human vestments (cotton and woollen fibres of various colours); *essences of flowers* (odour of the air after a summer shower); vapour of *characin* (cause of the odour of marshy soils and ditches); traces of *iodine* and *hydrochloric acid* (in sea-air); traces of *nitric acid* (in the rain of thunderstorms); *ammonia*; dust of *carbonate of lime*; *volcanic ash*, grey, red, and black; *organic matter* of various kinds, that can be condensed in strong sulphuric acid, which it turns brown.

In the dense London fogs *seleniuretted hydrogen* has been mentioned, but without sufficient proof, as the cause of the choking sensation these fogs produce. *Sulphurous acid* is often present (from the combustion of pyritous coal, and in volcanic regions); it first *reddens* blue litmus paper, and then *bleaches* it. *Hydrochloric acid*, present in the air near chemical works, only *reddens* litmus, and turns the leaves of trees yellow. *Sulphuretted hydrogen* is often present in town

air, and *organic compounds of sulphur*, due to the fermentation of sewage and refuse of various kinds. *Ammonia* is present in the air of the open country to the extent of 3 parts for every 100 parts of carbonic acid; on some occasions it has been detected in much larger quantities in the air of Regent Street, London, where it turns to a blue colour a strip of moist red litmus paper carried on the hat. London air, also, often shows *carburetted hydrogen*, due to gas escapes; and, in the country, *proto-carburetted hydrogen*, or marsh gas, constantly rises in bubbles from stagnant pools which have much decaying vegetable matter in their mud, and finds its way into the air. This is also the gas which issues from the seams of coal in mines, and gives rise to disastrous explosions. Boussingault has detected it, more than once, in very minute quantities, in atmospheric air taken from various localities, far from towns.

The germs of various *pathogenic bacteria* can be collected in cotton wool, or on plates of glycerine, such as I have before mentioned; they can then be transferred to a sterilized gelatine mixture, in which they develop, and can afterwards be inoculated into the tissues of various animals to prove their toxic nature.[1]

Dr. Miguel has collected the *urea ferment* in the streets of Paris (and it may readily be met with in our metropolitan railway stations). Previously to this,

[1] Pasteur used guncotton for these experiments, which, after it has collected the germs, etc., in the atmosphere, can be dissolved in a mixture of alcohol and ether, and so set them at liberty for microscopic examination.

Pasteur collected the *grape vine ferment* during vintage time in France. I was desirous of repeating this experiment of the celebrated *savant*, whose friendship I enjoyed during my four years' residence in Paris, and whilst a heavy gale was blowing for about three days in London, at the time of the vintage in France, I passed some hundreds of gallons of air into a solution of sugar with the hope of thus catching some grape ferment. The solution was afterwards placed in a stove, kept, for some days, at about 70° Fahr. to promote fermentation. No alcoholic fermentation was obtained (I am afraid my solution contained too much sugar); but the bottle having been kept hermetically sealed for several months, there developed in it an extraordinary brownish-white fungus in long filaments, a species of *Byssus*, whilst the liquid became of a golden-yellow colour, and slightly acid.

CHAPTER XII.

Air essential to Sound—Mountain Air—Dr. Viault's important Observation—Height of the Atmosphere—Determination of Altitude—Effects on the Barometer and Thermometer—Temperature at the Limits of the Atmosphere—Hermite's recent Experiments with small Captive Balloons—Heights of Clouds—Determination of Water-vapour in the Air—The Rain-band of the Spectroscope.

ATMOSPHERIC air is a good *conductor of sound*, and a better conductor when moist than when dry.

If no atmosphere existed, sound would be absent from our world.

As we rise on the mountains, the air becoming less and less dense, sound diminishes remarkably; so that the crack of a rifle is quite a slight noise in the hands of a Chamois hunter in the Alps; and even thunder is far less terrible on the mountain heights than in the valleys.

Mountain air affects the breathing of persons unaccustomed to it: the air being less dense contains *less oxygen in a given volume*, whilst the capacity of the lungs, of course, remains the same. But Nature ensures a proper degree of hæmatosis by *increasing the number of blood-corpuscles of those who reside for any length of*

time on the mountain heights. This most remarkable discovery is due to Dr. Viault, of Bordeaux (France), who made it originally on the slopes of the Andes, in South America, and has since confirmed it in his travels on the mountains of Europe.

With regard to the action of mountain air upon the mental powers, Professor Janssen, during his recent ascent of Mont Blanc, found that when he was not exhausted by physical exertion, his mental functions remained perfectly clear. When he took physical exercise he was rapidly fatigued, and quite unfit to perform any calculations, or other mental labour.

A number of interesting questions and some remarkable phenomena are connected with the *height* to which our atmosphere extends above the level of the sea. With this subject is connected the curious problem, *whether gases, deprived of all pressure, can expand indefinitely*, which formerly attracted the attention of my late friend M. Babinet, the eminent successor to François Arago, at the French Institute, and *Bureau des Longitudes*, and to which I hope to refer again.

Some have thought, indeed, that the Earth's atmosphere has no limit. Others suppose that at an elevation of forty to fifty miles the elasticity (tension) of the air, and the attraction of gravitation, must balance each other.

Applying to the total height of the Atmosphere the law of the diminution of density as observed in the lower strata of air in which we live, we arrive at the conclusion that at a height of about forty-five miles,

the atmospheric air must be as rarefied as in the exhausted recipient of the best-constructed air-pumps.

From a practical point of view, it may be stated, at once, that *air in which man may live does not extend to ten miles above sea-level*, probably not to eight miles, as proved by recent balloon ascents.

It has been attempted to ascertain the *absolute height* of the Earth's atmosphere (which the eminent meteorologist, Dr. Buist, declared to be unknown), by considering the height of the Aurora borealis, and that at which meteors are seen to shine. A distinguished American observer, Mr. Newton, once expressed the opinion that there must be some kind of an atmosphere at 500 miles above the surface of the Earth.

The height of luminous meteors, determined parallactically by various observers, gives results showing that they shine at very different heights, namely, 48 miles, 72 miles, and 132 miles.

The ingenious polarization experiments made by the French Astronomer, M. Liais, in his voyage to Rio de Janeiro, alluded to in my work on *Meteors* (chap. xix.), point to 200 miles as the height to which the Earth's atmosphere actually extends.

It seems to be beyond doubt that the Aurora borealis glows at a greater elevation than that at which shooting-stars become visible.

The celebrated Laplace, in his *Exposition du Système du Monde*, says the solar rays reflected from the molecules of air before the rising, and after the setting of the sun, producing what is termed *dawn* and *twilight*, which

spread to more than 20 degrees from the sun, prove that the most distant molecules of the atmosphere are *at least* 30 miles above the Earth's surface. Now, if we suppose that a given volume of air, considered at the surface of the Earth, *increases*, as we rise, *according to the square of the distance*, the volume which corresponds to 45 or 50 miles, where the barometer would be at 0 inches (that is, where all pressure ceases), would be about 34,646 cubic miles, the cube-root of which gives about 32½ miles, a figure approaching very nearly to that of Laplace just mentioned.

As we rise in the atmosphere it becomes more rarefied; the diminished pressure affects both the barometer and the boiling-points of liquids.

Practically speaking, the barometer falls about $\frac{1}{10}$th of an inch for every 100 feet of elevation. Whilst at sea-level the atmospheric pressure of 15 lbs. to the square inch keeps the barometer at 30 inches, and the boiling-point of water at 212° Fahr., these figures both diminish in proportion to the altitude.[1]

Travellers sometimes make a rough guess at the altitude to which they have ascended on a mountain slope, by boiling the thermometer: there is a difference of some 4° to 5° Fahr. for every 1000 feet of elevation. Actual experiment has given the following results:—

[1] Atmospheric pressure varies *slightly* at sea-level in various parts of the world; it is slightly less in the tropics, and increases towards the poles. The same has lately been found to be the case for *gravitation* (Defforges, 1893). This is as it should be, for after all, atmospheric pressure is merely the effect of gravitation upon the material of the Earth's atmosphere.

At sea-level in England, water boils, according to my thermometer, exactly at 212° Fahr., when the barometer is at 30 inches. On the summit of the Waldeck and Hartz mountains in Germany, at 2000 feet of altitude, I found, *with the same thermometer*, 208° Fahr. as the boiling-point of water. At a height of 6800 feet, on the summit of the St. Gothard (Alps), 200° Fahr. has been noted. At Quito (South America), at 9340 feet, water boils at 195° Fahr.; on the summit of Etna (10,900 feet), at 192° Fahr.; and on the highest summit of Mont Blanc, at an elevation of 15,600 feet, the temperature of boiling water was found to be 182° Fahr.

The refrigeration, or coldness of the atmosphere, increasing as we ascend, the thermometer is usually about 1° Fahr. lower for every 300 feet of altitude; but this varies somewhat with the locality, and with the direction of the wind at the time of observation.

The cold air of mountain heights throws out moisture in the shape of cloud; but as we ascend beyond this, the air becomes drier, and only on rare occasions, according to Fitz-Roy, have clouds been distinguished actually above the summits of the highest mountains.

Hitherto, no one has ascended in a balloon much above the summits of the highest mountains, says the eminent author just named; and it is not likely that it ever will be achieved, since man's existence at such altitudes is impossible. Small captive balloons provided with self-registering thermometers, and very light,

self-registering barometers made of aluminium, have quite recently been used in France, by Gustave Hermite, to ascertain the *temperature of the atmosphere at great altitudes.* At a height of 12,000 metres a temperature of $-51°$ C., and at 10,000 metres $-41°$ C. were noted.[1] Mendeleeff's calculations show $-42°$ C.; Vallot's observation on Mont Blanc $-45°$ to $-47°$ C., as the temperature at the extreme limits of the Earth's atmosphere,[2] and Glaisher from his dangerous balloon ascent in 1862, estimated $-40°$ C. Forty degrees below *freezing-point Centigrade* is the temperature at which quicksilver becomes solid; it corresponds also to $-40°$ Fahr. (72° below *freezing-point Fahrenheit*). Layers of fog, or cloud, lie at various heights, generally not exceeding two miles, and currents of wind set in different directions simultaneously; sometimes, clouds float in one current, sometimes in another, and occasionally between two currents (Fitz-Roy). On the slopes of mountains, and by balloon ascents, depths of more than 2000 feet of cloud have been measured.

Fogs, or clouds, are sometimes *dry*, and sometimes *wet*; in other words, they wet the Earth and objects on or above its surface, or they do not. This appears to be entirely dependent upon their electrical state (positive or negative).

A fog is exactly the same as a cloud; a traveller on a mountain is sensible of no difference; but the very

[1] Hermite, *Comptes-rendus* of the Paris Academy, 22nd January 1894.

[2] Vallot, *Comptes-rendus*, 5th February 1894.

highest clouds are supposed to consist chiefly of thin layers of snow, or ice crystals. According to one of our most eminent meteorologists, *no trace of cloud has ever been observed at a greater height than seven miles.*

The following heights to which the various kinds of clouds rise in the atmosphere is now generally admitted:—

Cirrus cloud to 35,000 feet; *cirro-stratus* to 27,000; *cumulus* to 15,000; and the *nimbus*, or rain-cloud, not above 5000 feet.

Two photographic cameras, placed half a mile apart, and in telephonic communication, suffice to determine the parallax of the clouds observed, and thus to get their exact elevation. We shall say more on this subject a little later.

The quantity of water vapour in the atmosphere, at any given spot upon the Earth, varies incessantly with the pressure and temperature, the time, and the direction of the wind. The point at which it is *saturated* with moisture, and deposits dew, or lets rain fall, is ascertained by the difference of reading between the *dry- and wet-bulb thermometers.*

Supposing the dry-bulb thermometer indicated 60° Fahr., and the wet-bulb 56°: the difference, 4°, being subtracted from the wet-bulb indication, leaves 52° as the temperature at which the air would be saturated with moisture. Or, if we double this difference and subtract the sum from the dry-bulb indication, we get the same result. The greater the difference of reading between these two thermometers, hanging side by side,

the drier is the air; when the difference is very slight, 1° or 2° only, rain is about to fall.

The *rain-band of the Spectroscope*, first alluded to by Professor Piazzi-Smyth as being due to aqueous vapour in the Earth's atmosphere, and as being situated on the red side of the line D of Frauenhöfer, increasing in intensity, or receding from the C line, according to the nearness or quantity of rain to be expected, seems to me to be less practical, and less reliable, than the indications of the wet-bulb and dry-bulb thermometers. The use of the spectroscope for this purpose requires further investigation.

When the air of the atmosphere is saturated, at the ordinary temperature of an English summer, it contains about 1 *per cent.* of moisture: *Carbonic acid* varies from 0·03 to 0·06 *per cent.*, and *water* from 0·6 to 0·9 *per cent.* The quantity of *ammonia* is to that of the carbonic acid as 3 is to 100, nearly.

Professor Macagno, in a series of interesting analyses of the air in the neighbourhood of the Observatory at Palermo, in Sicily, which stands only some 200 feet above sea-level, has shown that carbonic acid, and organic matter, increase in the air as the temperature rises; that rain invariably purifies the air; and that there is a slight diminution in the amount of oxygen during the prevalence of the *sirocco*.

CHAPTER XIII.

Air the only Gas that can be breathed—Important Work of the late Wilson Phipson—The Compressed-air Work of Daniel Colladon—Dr. Junod's Application of rarefied Air—Air-bath Establishments—Disinfection—Special Action of given Disinfectants—Absence of Microbes in Pure Air.

THREE-QUARTERS of a century ago, the late Dr. Thomas Thomson, of Glasgow University, pointed out in his celebrated work on Chemistry,[1] that *air is the only gas* which man and the higher animals can breathe for any length of time. Many gases are promptly fatal; others can be breathed only for a very short time.

This shows the immense importance of good ventilation in crowded edifices. Here I may be permitted to refer to the splendid results obtained by my late brother, Wilson W. Phipson, M.Inst.C.E., of London, to whose marvellous energy and indefatigable labours—ending, alas! in premature death—most of the largest public buildings in Great Britain owe their superiority in this respect, notably the Royal Albert Hall, the Banks and Clubs of London, the Universities and Medical Schools of Glasgow, Edinburgh, Liverpool,

[1] Thomson, *A System of Chemistry* (in four vols.), London, 1820.

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Birmingham, etc., all works obtained in public competition. His method is described in an excellent paper read to the *Institution of Civil Engineers*, and published in their Journal.[1] The application of air in motion to chemical industries, such as getting rid of acid vapours in gold refining, and chemical laboratories, etc., was also carried out most successfully by him for Baron Rothschild, and for the professors at the Glasgow and Edinburgh Universities, as well as in many other cases.

The great Swiss engineer, Daniel Colladon, who has recently departed from among us at 91 years of age, has also left an imperishable name, by his talented application of *compressed air* for the boring, and ventilation, of tunnels and mines. His blowing machines, worked by hydraulic pressure, by which the Mont Cenis and St. Gothard tunnels through the Alps were bored, were already under consideration as early as 1852.

The air-gun is one of the oldest applications of compressed air (1650); and the *briquet à air*, by which a lighted tinder is produced, by sudden compression, as I have already mentioned, dates back about two centuries.

Great economy would be realized if compressed air could be used in place of steam for locomotion. Some attempts have been made in this direction; among others, one by the French inventor, M. Julienne, about

[1] Wilson W. Phipson, *Journ. of the Inst. of Civil Engineers*, London, 1878–79. For a notice of his career, see the same *Journal* 1892.

the year 1852 or 1853, when the Swiss engineer just named first thought of his; and, also, by means of the hydraulic press. But neither compressed air, nor heated air (machines of Ericsson, etc.), nor electricity, have, up to the present time, been made to compete successfully with steam. In the case of such machines as that of Julienne, steam or some other motive power must be used to work the hydraulic press.

Air itself is the motor power in the *windmill*; and an ingenious apparatus of this description, known as the "Rollaston wind motor," is at present being experimented with in the neighbourhood of London, with the view of applying it to electric lighting by wind power.

With regard to the use of *compressed or rarefied air* as a therapeutic agent, Dr. Junod, a Swiss physician, whom I met in Paris in 1856, had invented in the early part of the century a metallic boot, coming up beyond the knee, where it was fixed by an air-tight bandage. A small tube near the foot, or ankle of the boot, allowed the air to be extracted by means of a small air-pump. This apparatus was used in cerebral congestion, etc., with apparently good results. The last occasion that came under my notice was in the case of the celebrated chemist, Regnault, after his fall through the skylight at the Porcelain works at Sèvres, of which he was then director. By the production of a vacuum in the boot, Dr. Junod hoped to withdraw the blood from the congested parts (head, lungs, abdomen) into the leg, and so relieve the congestion. The apparatus was, in fact, an extension of the dry cupping-glass.

Paul Bert, many years later, drew attention to his experiments with compressed oxygen; and it was hoped, at one time, that they would lead to a method of curing phthisis, anæmia, asthma, etc. At the present day, there are to be found in Paris, Berlin, and other cities, one or two establishments where *air-baths*, or oxygen baths, at various degrees of pressure, are in operation.

Although I have no personal experience of these applications yet, having been for the last fifteen years on the staff of two medical journals, it has been my duty to record, from time to time, any progress that has been made in this direction. The latest researches on the subject are embodied in the observations of Dr. Brugelman, of Berlin, who, after a lengthened experience, has come to the conclusion that *compressed air is a better remedial agent than compressed oxygen.* He declares that it produces excellent results in the treatment of asthma, emphysema, bronchial catarrh, chlorosis (anæmia), pleurisy, and valvular disease of the heart. He has reported two cases of chlorosis in which much benefit followed the compressed air treatment. Emphysema he found most benefitted by *rarefied air.*

It must be remarked, however, that this kind of treatment has not yet gained the suffrages of the generality of practitioners.

Quite recently, the *compressed air bath* has been used by Dr. Hovent, of Brussels, in the treatment of deafness in a girl 13½ years of age, who had gradually become deaf, from birth, and had undergone several operations

with little or no benefit. The compressed air bath is said to have cured this case in about a fortnight, which is, certainly, very remarkable.

Another very important subject is the *disinfection of air impregnated with the germs of disease.*

The best general disinfectant of the air appears to be *chlorine gas acting in daylight*; then come bromine and iodine vapours, also sulphurous acid, obtained by burning sulphur, which is often used for disinfecting the wards of the Paris hospitals.[1]

The most powerful disinfectant of the air, among organic substances, is the *essence of cinnamon*; then come essence of cloves, essence of turpentine, carbolic acid, thymol (essence of thyme), menthol (essence of mint), salicylol, eucalyptol (essence of Eucalyptus), and camphor.

The essential oil of cinnamon sprayed into the air of a hospital ward where malarial fever raged, has been found to hasten the cure of the patients, and to check the spread of the disease very promptly. Unfortunately it is rather expensive.

I have found chlorine gas (obtained by pouring dilute hydrochloric acid on to chloride of lime) arrest the spread of scarlatina and small-pox, in a very remarkable manner, on more than one occasion.

Eucalyptol vapour is said to arrest the spread of influenza, and menthol vapour, sniffed violently into the nostrils at frequent intervals until warmth is felt

[1] See my *Health Notes and Curiosities of Medical Science,* London, 1898, p. 24 *et seq.*

in the throat, will arrest coryza, or "cold in the head," in a few hours.

But I have observed that certain disinfectants have a special action on certain disease germs; thus, essence of cinnamon appears most effective in *malaria*, essence of mint for *consumption*, essence of eucalyptus for *influenza*, etc. These are facts which are only now coming to light for the first time, and require careful investigation.

That the most terrible diseases, such as cholera, tuberculosis, diphtheria, scarlatina, small-pox, and traumatic fever, not excepting puerperal fever, can be mitigated, and perhaps prevented altogether, by thoroughly disinfecting the air of a locality, is now beyond doubt. The rapidly diminishing incidence of cholera among the protected communities of Bengal, is a striking proof of the capabilities of modern sanitary science in this respect, no less than are the marvellous results yielded by surgical antisepsis during operations.

According to Dr. Cortes there are no *pathogenic microbes*, or disease germs, in the atmosphere of Cape Horn. The Fuegians did not know anything of small-pox, measles, scarlatina, or diphtheria, before the inroads of civilization. Prior to the visits of the missionaries, even pulmonary consumption was unknown, and tuberculosis has only begun to establish itself since the year 1881.

Dr. Contsand has made a study of the atmosphere of the Arctic regions as regards its contents in *bacteria* (microbes, disease germs). An examination of the

air, the water, and the soil of Spitzbergen brought to light the extraordinary poverty of these regions in bacteria. Whilst Dr. Miguel found in the streets of Paris an average of 51,000 bacteria in the cubic yard of air, the air of the Arctic seas contained only 3. In the water of Spitzbergen no microbes of any kind were found. A few were detected, however, in the water of the island of Jan Mayen. The *Bacillus subtilis*, so commonly met with in the different countries of Europe, was not to be found in the soil of these Arctic regions.

These remarks will, doubtless, be found to apply with equal force to many other localities, hitherto unexamined.

Some places have been noted as "health resorts," the atmosphere being remarkably pure there, neither too hot nor too cold, with no sudden oscillations of temperature, and the degree of moisture being likewise moderate. Among other places, Southern California has of late years been much extolled in this respect. It is claimed that there is to be found the *ideal climate* of the celebrated German physician and author, Hufeland. Photographs have been taken of Indians, whose great age appears to confirm the popular legend that in Southern California and Arizona the aboriginals never die—"they just dry up, and are wafted away by the wind."

A few years ago, General G. M. Kober pointed out that if *inorganic dust* can travel through the atmosphere to such immense distances (as was noticed, for instance,

in the case of the volcanic ash of Krakatoa), there is no reason why *disease germs* should not be wafted by the air to still greater distances. But the sea air appears to destroy them: *the distance to which infectious microbes have been carried out to sea,* as far as actual experience has hitherto gone, *is under* 120 *nautical miles.*

CHAPTER XIV.

Air of Inhabited Districts, of the Country, of the Sea-coast, and of the Ocean—Quantity of Carbon in the Air of a London Music Hall—Quantity of Carbon in the Earth's Atmosphere —Quantity of Carbon in Organized Beings—The New Gas "Argon" — Forest Air — The Author's Observations in Waldeck, etc.—The Influence of Trees on the Air of Towns —Influence of Forests on Rainfall known to Columbus—The Author's Explanation based on direct Observation.

THE term *Atmosphere* should, properly, be applied only to the gaseous envelope of the Earth; whilst the term *air* is used to denote a limited portion of the atmosphere, such as the lower portion in which we live, the air of rooms, of mines, of forests, the air of the sea, etc.

Ordinary air, in inhabited districts, yields to analysis, in round numbers, 21 volumes of *oxygen* and 79 of *nitrogen*; it contains, on an average, 4 volumes of *carbonic acid* in 10,000 volumes of air, and in the open country this amount will fall as low as 3 parts in 10,000, whilst over the ocean, according to Beauvais, there is a mere trace of this gas in the air, a fact, doubtless, to be accounted for by the solubility of carbonic acid in water.

My late distinguished friend, Dr. Verhaeghe, of

Ostend (Belgium), found only $2\frac{1}{2}$ parts of carbonic acid in 100,000 *volumes of air on the coast*, which is more than 10 times less than is found in inland districts.

As carbonic acid is known to be very deleterious to consumptive patients, its *almost complete abscnce over the waters of the ocean* is one of the reasons that has caused physicians to recommend sea-voyages for sufferers of this kind.

Although the relative amount of *carbonic acid* in the air appears, at first sight, to be exceedingly small, its *absolute amount in the whole atmosphere* is exceedingly great. Let us take the average contents of the atmosphere in carbonic acid at 4 parts in 10,000. A room 25 feet long, 25 feet broad, and 16 feet high, would hold 10,000 cubic feet of air, with its 4 cubic feet of carbonic acid; and these 4 cubic feet of this gas would weigh 2455 grains and contain 607 grains of *carbon* (equal to a piece of charcoal about the size of a hen's egg).

A large music hall in London contains about 150,000 cubic feet of air, and consequently, the amount of carbonic acid contained in it will be 15 times 4, or 60 cubic feet, and the amount of carbon 15 times 607 grains, or more than $1\frac{1}{4}$ lbs.

When we pass from the consideration of the air, in rooms, large or small, to that of the Earth's atmosphere in its present condition, we get results almost beyond conception:—

The weight of the air overlying every square inch of the Earth's surface is in round numbers about 15 lbs.,

or 2160 lbs. on the square foot. So that every square foot of the Earth's surface has overlying it 2160 lbs. of air; and this quantity of air contains about $1\frac{1}{2}$ lbs. of carbonic acid, equivalent to nearly $\frac{1}{2}$ lb. of carbon.

The organized beings on the Earth's surface contain on an average 45 *per cent.* of carbon (nearly half their weight), and from a single acre of wheat land, some 2000 lbs. of carbon are taken in a single season. Now, if we reckon from acres to feet, we find that, during the whole period of its growth, this crop of wheat, which yields 2000 lbs. of carbon, has overlying it some 20,000 lbs. of carbon in the form of atmospheric carbonic acid, which is infinitely in excess of the wants of vegetation in this respect; and the *quantity of carbon in the entire atmosphere,* as carbonic acid, is far in excess of that contained in all living beings, both plants and animals, existing on the surface of the Earth, and in the inflammable carbonaceous minerals, such as coal, lignite, peat, etc., which lie buried beneath its surface, as far as we can estimate this quantity with any degree of probability.

The supposed new gas in the atmosphere, which has recently been brought before the public by Lord Rayleigh and Professor Ramsay, who have given to it the name of "*Argon*" (inert) on account of its absolutely inert properties, and which, they say, forms about 1 per cent. of atmospheric air, appears to several chemists to be an *allotropic form of nitrogen*, similar to what *ozone* is to oxygen; or a *protocarbide of nitrogen.* It remains as a residue when a mixture of oxygen and

nitrogen is submitted to a long series of electric sparks, until no more nitric acid can be formed in this way. This inert residue was observed by Cavendish, who first made this experiment, in the last century It weighs rather more than ordinary nitrogen, just as ozone is denser than oxygen. It is not absorbed by red-hot magnesium, as ordinary nitrogen is; and the figures given in the author's paper, read to the Royal Society, point to the probability of its being 3 molecules of nitrogen condensed into 2 molecules, similar to what the late Dr. Andrews of Belfast found to be the case with ozone, as regards oxygen. Lord Rayleigh had noticed that the nitrogen gas obtained from ammonia, or from nitric acid, weighed slightly less than the nitrogen obtained from the atmosphere, and this caused him to believe that the atmosphere contained some unknown constituent which increased the height of its nitrogen. This led to a series of very laborious researches, in which he was assisted by Professor Ramsay, and ended in the discovery of the gaseous substance they call "argon."

When oxygen takes the allotropic form of *ozone*, its characteristic properties are enhanced, its tendency to combine with other bodies is much greater, its activity is wonderfully increased. In the case of nitrogen, when it passes into the state of *argon*, its inert nature becomes even more apparent than it usually is, which is exactly what we should expect.[1] Argon may, never-

[1] See Phipson, *Chemical News*, February 1895, and Berthelot, *Comptes-rendus*, 11th March 1895.

theless, prove to be a *carbide of nitrogen* containing half as much carbon as cyanogen, which would have the same density.

The beneficial influence of *forest air* has often been ascribed to a large amount of oxygen, less carbonic acid, and the presence of balsamic, aromatic vapours. But analysis shows that there is very little, if any, extra oxygen during the day, and rather more carbonic acid at night, than in the open air of the country.

The wind constantly tends to mix the forest air with that of the fields and plains, and the hygienic influence of the former must be ascribed in great measure to its *freedom from dust and disease germs.* It is, so to say, filtered air.

The diurnal variations of temperature are also slighter in forests than in the open country. Woods are usually warmer than the adjacent atmosphere. I have noticed that the forests on the hills of Waldeck, in Germany, appear to smoke, after heavy rain in June, an effect due to the moisture rising with the warm air of the woods into the cooler atmosphere above them. I have seen the same effect on a garden wall in London, which being heated by the summer sun for some hours, emitted steam after a heavy shower of rain.

Once in a hot crowded room in Paris, I witnessed a similar condensation of invisible moisture into visible steam, from a reverse process. It occurred over plates of ice handed to the guests: *each ice appeared to smoke,* like a miniature volcano, producing a most singular effect.

The air immediately over the tree tops, and at the edge of a forest, has been found to contain more *ozone* than in the interior of the woods, where any ozone would be at once absorbed by decaying leaves and branches.

Investigations of cholera and yellow fever epidemics have lately demonstrated that disease germs always avoid towns and villages surrounded by forests; and that after the clearing of forest lands, these epidemics appear in localities which, previously, had never been visited by them.[1]

The *influence of trees on the atmosphere of towns* has lately been examined by Dr. Jeannel. The problem may be solved, he says, in the following manner: The carbon converted into carbonic acid by one man, *per annum,* is about 1400 lbs. The carbon absorbed, *per annum,* as carbonic acid, by an acre of forest is approximately 8050 lbs. It results from this, that trees planted in towns can have but little influence on the purification of the air defiled by animal respiration; for, according to these figures, it would require some 300,000 acres of forest to absorb the carbonic acid produced in a year by a city which has a population of two millions of inhabitants.

How, then, does it happen that the air of Paris, for instance, which has been so often analysed, always shows as nearly as possible the same composition: oxygen 21, nitrogen 79?

It is the movement of the atmosphere, which wafts

[1] *Ann. of the Universal Med. Sciences,* 1894.

away the carbonic acid to the vast forest tracts of the globe—the grand ventilation of Nature; so that the atmosphere, as a whole, gets back, volume for volume, as oxygen, all the carbonic acid produced in densely-crowded cities.

The *influence of forests on rainfall*, which was already noticed in the days of Christopher Columbus, has been so often written about that I need say little on this subject. I have already alluded to the steam issuing from the woods on the mountains of Waldeck after heavy rain in summer, a phenomenon showing that the atmosphere above the woods is cooler than the air in their interior. I have also been struck by the rapid manner in which the evenings cool after hot days in these woody districts. The forests presenting a *rough surface* radiate heat more rapidly than the *smooth surface* of the open country. Thus, after very hot days in June, when the thinnest cloth coat, or no coat at all, was most acceptable, I found it necessary to put on an overcoat some time before sunset.

This radiation, so marked from the rough surfaces of forest lands, will readily account for the condensation of more cloud, and consequently a greater rainfall in wooded districts; hence also increased fertility, and a more prosperous condition of the inhabitants.

A well-known French hygienist traces the arrest in the increase of population, and even depopulation, in thirty departments of France to the disappearance of forests in the mountainous districts.

CHAPTER XV.

Cold Air more dangerous than hot Air—The late Dr. Meisser's Opinion—Effects of Sojourn in the Tropics—Temperature Observations—Altitude, Dryness, Humidity—Carbonic Acid in London Fogs—Air over Stagnant Water—Hydrocarbon Gases in the Air of certain Localities—The Air of Mines—Air of Bedrooms—Air of Fermentation—Air of Wells and Sewers—Air over active Volcanoes—Air of Mountains—Effects of Arsenic—Air of Treeless Plains—Air of the Arctic Regions, and that near the Snow-line on Mountain-slopes—Air of the Tropics—Air in Epidemics of Cholera.

Cold air produces a higher death-rate than hot air, as was professed in 1850 by the late Dr. Meisser, the distinguished Professor of Comparative Anatomy at the University of Brussels, and his opinion was fully confirmed by Dr. Benjamin Ward Richardson of London, in 1890, or forty years later.

Meisser especially pointed out that cold was more dangerous than heat to aged persons. The saturation of the air with moisture increases the unfavourable effects of a cold atmosphere. The danger from consumption is much greater in winter than in summer.

With regard to *hot air*, it is known, at present, that Europeans who have lived for some time in the tropics are much less able to withstand the heat than are new-

comers. The Anglo-Indian statistics supply us with direct proof of the diminished vitality (or resisting powers) of Europeans living for a long time in the tropics.

The *temperature of the air* follows the course of the sun; it is coolest towards the break of day, just before sunrise, and hottest about two or three in the afternoon.

To obtain a forecast for the day, it is necessary to *observe the thermometer always at the same hour,* say at nine o'clock in the morning. Its indications will then serve to establish whether the day will be colder or warmer than the preceding day.

In very variable weather the thermometer will fluctuate considerably during the twenty-four hours, both by day and by night, as cold or warm currents of air affect it; but such sudden changes are not common. They are more frequently observed with us in England during the cold winter weather, when the night temperature is sometimes higher than the day temperature, just as with a patient suffering from fever.

The air on a cloudy night is always warmer than it is on a clear night when the Earth radiates its heat into space. Clouds check this radiation. We cover up plants to preserve them from cold on clear nights; their radiation often cools them down to freezing-point in spring, and in summer causes them to be covered with dew. When the sky is overcast there is less danger from frost, and no dew is deposited.

The temperature of the Earth's atmosphere is evidently affected by the position of the planets. The

approach of Mars to the Earth in 1892, when it appeared in the sky as brilliant as Jupiter, was followed in 1893 by most intense heat at Bombay, New York, London, etc., etc. (the law is that when bodies (or atoms) approach, heat is the result, and when they move away from each other cold results). The going away of Mars was probably the chief cause of the intense and prolonged winter of 1894–95, which will be long remembered in London (especially by the Water Companies), and in the South of France and northern Italy, where its effects were first felt.

The *cold days of May* (about the 10th to 12th) are most probably to be ascribed to the interposition at this period between the Sun and the Earth, of the November meteor streams (13th and 14th); to the *melting* of snow and ice on the mountains, by which enormous amounts of atmospheric heat are absorbed, and to the presence of floating icebergs in the Atlantic.

With regard to *altitude* in the atmosphere, it has recently been found in India that 7000 feet is about the best height for a permanent residence for Europeans, 5000 feet being the lowest level at which malarial fever can be avoided.

In South America yellow fever breaks out only in localities where the temperature reaches to 70° Fahr. and above. At elevations where this temperature of 70° is never exceeded, the inhabitants are almost exempt from this terrible epidemic.

Dryness of the atmosphere, with liability to dust, cold, fogs, winds, and rapid fluctuations of temperature, con-

stitutes a very bad climate for most invalids. The chief reasons why sea air is so conducive to health reside in its *greater humidity*; greater purity as regards carbonic acid and animal effluviæ; greater density, whereby the lungs take in a rather larger amount of oxygen at each inspiration; and, generally, a larger amount of ozone. A modern American writer, Dr. Baruch, is enthusiastic on the value of pure air for consumptives, when this purity is combined with conditions which afford the best opportunities for an out-door life.

On the summit or higher slopes of a mountain, there is less carbonic acid in a cloud or fog than is found in the air of the same locality in fine, clear weather. This is a curious and interesting fact, since the very reverse is found to be the case in large towns. For instance, when the streets of London are obscured by a dense fog, the quantity of carbonic acid in our atmosphere is greatly increased; this gas appears to be absorbed by the fog, and its diffusion through foggy air is much less rapid than through clear air.

Dogs that fall senseless in the *Grotta del Cane*, near Naples, from the effects of carbonic acid that oozes from the soil, soon recover when placed in the pure open air, and Dr. Marcet has lately shown that the effects produced on the chemical phenomena of respiration by breathing and re-breathing eight gallons of air in a closed vessel for the space of five minutes, pass away in less than six minutes after the breathing of fresh air has been resumed.

Hence it is evident that persons who are called upon

to make a prolonged stay in ill-ventilated rooms, should go into the open air as often as possible, if only for a few minutes.

The *air over stagnant waters* in the country shows large quantities of carburetted hydrogen (marsh gas), as well as carbonic acid, due to the gradual decomposition of vegetable matter in the mud. When this mud is stirred up, abundance of this inflammable carburetted hydrogen gas can be collected, as was first shown by Campi of Milan, a learned ecclesiastic, and friend of the celebrated Volta, about the year 1760. It often bubbles up spontaneously, and can be set alight on the surface of the water. It is probably the cause of the will-o'-the-wisp, or *Ignis fatuus*, and is the same gas that oozes from the seams of coal and gives rise to colliery explosions.[1]

In some countries in the East, and in America, this carburetted gas burns permanently at the surface of the soil, and has done so for a very long period of years. But it should be remarked that, in some cases, the flame is not due to marsh gas, but to some other hydrocarbon of the naphtha or petroleum nature. It is always easy to distinguish between the two, as marsh gas burns without smoke and without odour, other hydrocarbon gases producing both smoke and a more or less fragrant odour.

The air of mines also shows the presence of this same marsh gas, which oozes spontaneously from the seams of

[1] See Phipson, *Familiar Letters on some Mysteries of Nature*, where an entire chapter is devoted to the phenomena of the *Ignis fatuus*.

coal, especially when the barometer falls rapidly after having remained very high for some time; and, when fired, occasions the dreadful explosions of which we read too often. The putrefaction of animal matter, such as the bodies of dead dogs, which are not unfrequent in coal mines, may give rise to *ignis fatuus*, and some of these accidents may, perhaps, be thus accounted for. They will continue to occur so long as mines are constructed in such a manner as to render complete ventilation impossible. Hitherto chemists have not discovered any substance that will absorb, or destroy, this gas as fast as it is produced. I once imagined that chloride of lime might prove effective, but have had no opportunities of making experiments on the subject.

The *air of bedrooms* is rendered unwholesome by animal effluviæ, but chiefly by carbonic acid. In the bedrooms of consumptive patients small buckets of *hydrate of lime* (slaked lime) should be placed, to absorb the carbonic acid as it is produced; and should be renewed every two or three weeks. The air may also be disinfected by exposing on the chimney shelf a little *essence of peppermint*, or of eucalyptus. The *air of hospital wards* is best disinfected with sprays of essence of cinnamon, or of eucalyptol, the odours of which are agreeable. They are quite as antiseptic as carbolic acid, which is highly poisonous, and has a disagreeable odour. But, as I have already stated, every disinfectant has its appropriate use; some appear to act better than others in certain given circumstances.

The *air of fermentation* which is found in wine vats

and breweries is fatal to man, on account of the large amount of carbonic acid it contains: it extinguishes a lighted candle. Deaths have occurred, during vintage time, by men incautiously coming under the influence of this air. Being much heavier than ordinary atmospheric air, it flows over the vats, like water, and forms a thick layer on the floor of the shed or cellar. A small quantity easily induces sleep, during which a workman will succumb to its effects.

The *air of wells and sewers* is likewise dangerous to workmen who enter it before depriving it of its carbonic acid. This can be done by means of slaked lime, or by forcing in fresh air, to displace the foul air. The workman should assure himself that a candle will burn brilliantly in this air before he descends. Besides carbonic acid, the air of sewers often contains sulphuretted hydrogen, and volatile organic compounds of sulphur, which have been observed to be rapidly fatal to rats; and sulphuretted hydrogen was once actually used to destroy rats in the Paris sewers by the celebrated chemist, Baron Thenard, in the early part of this century.

The *air over active volcanoes* contains sulphurous acid and hydrochloric acid. It is extremely dangerous to excursionists on Vesuvius *when the wind happens to turn in their direction.* It was this air that killed Pliny the Naturalist, in the year 79.

The *air of the sea,* as I have already mentioned, is often impregnated with salt, especially during rough weather, and in hurricanes with rain at Barbados, and elsewhere, the *rain* is often salt.

The *air of the mountains*, to which I have also alluded above, is purer, freer from carbonic acid and moisture, but *less dense* than that of the plains. It affects respiration most painfully, especially when the sufferer is fatigued, as less oxygen is taken in at each breath. But, as we saw when I alluded to the interesting discovery of Dr. Viault, the number of red corpuscles of the blood is increased by a continued sojourn in mountain air, so that, in time, *hæmatosis*, or oxidation of the venous blood, is carried on as usual. To promote this, the Tyrolean mountaineers have recourse, sometimes, to *arsenic*, as a tonic. This is a dangerous practice, giving excellent results at first, but when once the period of arsenical poisoning is reached (which comes on very gradually and insidiously) the patients are often beyond the reach of medical art, and many have thus succumbed early in life.

The *air of treeless plains*, distant from inhabited districts, is remarkable for its dryness, its density (if these plains are not elevated), and its dust. The wind gives rise to *dust-storms* (or sand-storms) over the deserts of Sahara, Gobi, etc., which have been often described in works on Meteorology.

If the plains are covered with grass, the air is pure and healthy, and devoid of dust.

Heated air, which causes the phenomenon of *the mirage* in the hot, sandy deserts, produces the same curious effect in our own temperate climate, as I found as early as 1856;[1] only, in this country, on our sea-

[1] Journal *La Science*, Paris, 1856, and *Comptes-rendus* of the Paris Academy, 1857.

coasts, or long straight thoroughfares, we must sit down upon the ground in order to place ourselves in the layer of heated air that produces this curious effect. Then men and animals at a distance appear much taller than they should, according to the laws of perspective, and their images are seen as if reflected in a sheet of water. Several times have I witnessed this phenomenon during the hot days of summer on the sandy coast of Flanders, and also in the neighbourhood of London.[1]

The *air of the Arctic regions*, and that which lies above the snow-line on mountains, is *dry* and *cold*. When not in motion man can support its effects in spite of its exceedingly low temperature; but *when in motion* it cannot be resisted with impunity; and it is then absolutely necessary to seek shelter, as was vividly pointed out by the American Arctic explorer, Dr. Kane, who succumbed not long after his return from his arduous enterprise, and at a very early age. But there is a certain difference between the air of the Arctic regions and that of a corresponding latitude on the slope of a mountain, which is indicated by the structure of the plants which grow in these regions: When the air of the Arctic regions is compared with that of a

[1] The results of my meteorological observations on the coast of Flanders were described to the Paris Academy of Sciences in 1857. It was there (and afterwards in Paris, and again near London) that I first witnessed the curious phenomenon of *rain without clouds*; and, on one or two occasions, *frozen rain* which fell in pear-shaped solid drops. Once also, at Ostend, I was able to convince myself that lightning occasionally occurs among clouds near the zenith, without being followed by the slightest noise of thunder.

corresponding station on the Alps, the former is found to contain much more moisture, and the leaves of the *same species* of plant (Saxifrage, or *Salix*, for instance) are invariably thicker than they are when growing in the mountainous district.

The *air of the Tropics* is generally *hot* and *moist*; furniture and musical instruments become unglued, and valuable violins have been known to fall to pieces in India, and the West Indies, soon after their arrival from Europe. I have already alluded to its effects upon the health.

With regard to the *air in cholera epidemics*, Glaisher and others have drawn attention to a peculiar *blue mist* which occurred in London and its neighbourhood during such an epidemic; but nothing at all satisfactory was the outcome of this observation. Early in the present century, it was noted by Figari, then Professor of Botany at Abuzabel, in Egypt,[1] that during the cholera epidemic of July and August 1835, several kinds of grasses, especially Maize (Indian Corn), were killed, over large districts, by blight; and the peasants who used the leaves of these plants for their cattle, or for themselves, contracted severe illness in every case.

[1] This gentleman published in 1867–8 an important paper on the cultivation of the opium poppy in Egypt. See *Ann. pharmaceutique de Reveil et Paris*, etc., Paris, 1868, p. 330; *Sur la Culture du Pavot à Opium*, etc., par Figari Bey.

CHAPTER XVI.

The Movements of the Atmosphere—Barometer and Thermometer—Cause of their Reverse Movements—Expansion of Air—Diurnal Oscillations of the Atmosphere—Fluctuations of the Electric State of the Air—Velocities of the Wind—Cause of the Movements of the Barometer — English Weather — Cyclones—History of Rotatory Storms—Small Local Cyclones.

THE movements of the Atmosphere have been extensively studied in modern times. We are far away from the days of Howard and Wells, whose ingenious observations laid the basis of the modern science of Meteorology; but only men like Fitz-Roy and Maury, who have navigated the seas for many years, can hope to grapple successfully with the Physical Geography of the Atmosphere.

The prime cause of the great movements of the air is *heat*, that mysterious power which, confusing itself with light and electricity, may justly be termed the *soul of the Universe.* The terrestrial sources of heat, and that derived from solar radiation, are at present nearly equalized, but the evaporation of water (which forms about two-thirds of the Earth's surface), followed by its condensation from steam to water, and to ice, yielding up enormous amounts of *latent heat*, exhibits a

constant, alternant source of production, and distribution, of cold and caloric, upon which depend the various climates, the regular, periodic, and variable winds, the zones of vegetation, the currents of the ocean, and, in fact, the whole life of the globe.

The same mysterious power, called heat, or caloric, which causes the circulation of the sap in plants, and of the blood in animals, circulates also the air of the Atmosphere, and the waters of the Earth, and keeps them in constant motion; for, as I said many years ago in a former work, "*movement, like matter, is universal.*" [1]

The vane makes its rotation, in our hemisphere, in the same direction as the Sun, a fact which was perfectly well known in the most remote antiquity (see Thales, and other ancient philosophers, quoted by Dove, in his *Law of Storms*), and the reverse occurs in the Southern hemisphere.

The warm wind and the cold wind (originating, respectively, at the tropics and the poles) alternate one with the other. When the warm wind displaces the cold wind, the change commences in the higher regions of the air, and the *barometer falls before the thermometer rises.* When the cold wind takes the place of the warm wind, the change occurs in the lower strata of the air, and the *thermometer falls before the barometer rises.*

When cold air descends into warm air, fog is produced; the descending current beats down the smoke of our cities, and disperses it over the surface of the Earth.

[1] Phipson, *Familiar Letters*, etc., The movements of plants.

According to the very exact researches of Magnus, of Berlin, on the *expansion of air* from 32° Fahr. to 212° Fahr., it follows that air at the freezing-point of water expands $\frac{1}{491}$th part of its bulk for every degree of heat of Fahrenheit's scale.

Thus, 491 cubic inches of air at 32° Fahr., become 492 at 33°, 493 at 34°, and so on, increasing one cubic inch for every degree Fahrenheit.

A contraction of one cubic inch occurs for every degree below 32°. Thus, 491 cubic inches at 32° become 490 at 31°, 489 at 30°, 488 at 29°, and so on.

This shows that atmospheric air taken at the freezing-point of water has its volume doubled at 491° Fahr.; and when heated up to 982° Fahr. (a low red heat) its volume is exactly tripled.

With regard to the *diurnal oscillation of the atmosphere*, the following little table is universally admitted:—

At 4 a.m. there occurs a *first minimum* of the barometer.

10 a.m.	„	*maximum* (highest).
4 p.m.	„	*second minimum* (lowest).
10 p.m.	„	*second maximum.*

These *regular oscillations of pressure* are easiest perceived at the sea-coast in the equatorial regions, where they are regular enough to allow us to judge of the hour without resorting to a watch. They are difficult to put in evidence in our temperate regions, but it can be done, and they appear, *like the daily magnetic variation*, to be intimately connected with the position of the sun in the heavens.

The *fluctuations of the electric state of the atmosphere*,

as denoted by the needle of the galvanometer-electroscope, are as follows:—

At 2 a.m., *minimum.*
10 a.m., *maximum.*
2 p.m., *second minimum.*
10 p.m., *second maximum.*

These are average results for our temperate zones, and they correspond with the *dryness* and *moisture* of the air (dry air, bad conductor; moist air, good conductor).

If we add together the angles of oscillation of the galvanometer needle during the *summer*, we get 33°; and during the *winter*, 799°.

The rapidity with which the air moves over the surface of the Earth, according to circumstances, can be determined by means of the *anemometer*, an instrument now in daily use in the Observatories. In round figures it may be put down as follows:—

Wind scarcely perceptible, . .	1	yard	per second.
Moderate wind, ...	2	yards	per second.
Fresh breeze (spread out the sails),	6	,,	,,
Stiff wind (best for windmills), .	7	,,	,,
Strong breeze (quick sailing), .	9	,,	,,
Half a gale (take in top sails), .	12	,,	,,
Very strong wind, . . .	15	,,	,,
Impetuous wind, or gale, . .	20	,,	,,
Very heavy gale, ...	27	,,	,,
Hurricane, ...	36	,,	,,
Furious hurricane (overturning buildings, etc.), . . .	45	,,	,,

A wind with a velocity of forty yards a second will produce the most prodigious effects, carrying before it all kinds of solid materials, such as tiles, bricks, beams, stones, and even iron, to a considerable distance.

In 1715, the Academy of Bordeaux offered a prize for the determination of the *cause of the movements of the barometer*. It was awarded to M. O. de Mairan, of Beziers, who corroborated the opinions of the English observers, Hawksbee and Halley, namely, that *the chief cause of these movements was the wind.* This was established on the principle that we must distinguish between the *absolute weight* and the *relative weight* of a body. The absolute weight (or pressure) cannot be altered except by an addition, or subtraction, of substance; but the relative weight may vary without any change in the absolute weight; and it is on this change in the relative weight that the movement of the barometer depends: When the atmosphere is in a state of repose it presses upon the Earth with its whole absolute weight, but when it moves it only presses by its relative weight. Thus a ball that rolls on a flat table weighs, or presses, less than when it is quiet.

This opinion is now generally adopted, though it was, at first, objected to by some philosophers.

We should add, for our English climate, that north winds, bringing *heavier* air than south winds (on account of the greater moisture in the latter, and because the air of the former is colder and denser), invariably raise the barometer.

Barometric observations, carried on simultaneously

in the principal towns of Europe, have led to the discovery of a curious phenomenon, namely, a vast wave of high pressure, followed by one of minimum pressure, which traverses the whole of Europe, from the English coasts to those of the Black Sea, in the space of four days. They are real waves, like those of the ocean, which, according to Professor Jamin,[1] flow regularly across the Continent, from West to East. The wave of low pressure brings tempestuous weather, of which notice can be given beforehand by telegraph.

It has been long known that our English weather comes chiefly from the West, that is, from the Atlantic. It is to the predominance of the westerly winds that we owe the best qualities of our climate. But besides these genial and refreshing breezes, wafting their warmth and moisture, and ozone, beneficial alike to men, animals, and plants, we are visited occasionally by *gales*, or storms of wind and rain, as disastrous to crops and shipping as the milder airs are agreeable.

Many years have elapsed since it was first imagined that these heavy gales of wind and rain might be *circulating*, travelling *storms*. It was De Foe, the author of *Robinson Crusoe* and a considerable number of other works, who in 1704, in his essay on *The Storm* (where special allusion is made to that of 1703), was the first to suggest this. His observation has culminated in the discovery of the nature and probable origin of *cyclones*, or rotatory storms, which travel across the Atlantic and visit our European shores at

[1] *Cours de Physique*, second edition, vol. i. p. 259.

certain intervals. We may show in a few words on what data the practical warnings now issued are based.

Winds are due to Solar heat affecting various portions of the Earth's surface in an unequal manner, and they are affected by the rotation of the Earth, which deflects the currents of air produced by this unequal distribution of temperature. But besides the regular winds ("trade winds"), which navigators have long ago learned to take advantage of, there is produced, frequently, in the regions comprised between the equator and the tropics, a translation of vast masses of air, having a rapid rotatory motion around a central axis. This axis is never precisely vertical, and whilst the air circulates around it, the entire mass is transported in a given direction, forming what is termed a *cyclone.* The direction of the rotation is tolerably constant: in the Northern hemisphere, it is the *reverse* of the motion of the hands of a watch—the wind blows or circulates from East to West through the North. In the Southern hemisphere, the contrary occurs: the wind blows round from East to West, by South, that is, the rotation is in the *same* direction as that taken by the hands of a watch.

These cyclones constitute the great tropical storms called hurricanes, or typhoons; they are the more severe, generally speaking, the smaller their diameter.

At their origin, this diameter is comparatively small, but increases as the cyclone travels away from the locality of its birth. Thus, some cyclones which had,

at starting, a diameter of about 180 miles, end in attaining a breadth of 1500 miles.

The central portion of the cyclone is relatively calm; the maximum velocity of the air is found at a certain distance from this centre, beyond which it again diminishes gradually in force. In certain points of the cyclone the wind is very violent, and in some instances has been known to blow at the rate of upwards of 120 miles an hour.

The rate at which a cyclone travels from one part of the ocean to another appears to vary very little in the same quarter of the globe. From the American shores to Europe, it almost always progresses at the rate of about *thirty miles an hour*; so that we can calculate approximately the time which a cyclone will take to reach Europe, after it has left the American coasts.

The curve which, on a Chart of the World, would represent the course of the central point of the cyclone, has its concavity usually turned towards the east.

Every cyclone that travels thus across the ocean, has one side, one half-circle, in which the wind is more violent than on the other. This is termed the "dangerous side," because ships are more exposed there than in other parts. If we suppose an observer travelling in the same direction as the central point, the dangerous side is always *on his right hand in the northern hemisphere.* This is natural, because on this side of the cyclone the direction of the wind in its rotation and that of its progression are the same, and consequently add to each other. On the opposite side,

the wind rotates in a contrary direction to the progressive motion, and the latter, therefore, diminishes the intensity of the former.

One of the consequences of this rotation of the air around a central space, is to produce a rarefaction or diminution of pressure, in the latter region, so that in this central part of the cyclone the barometer falls very low. The course followed by this depression (lowest barometer) is that of the cyclone.

The data collected by vessels crossing the Atlantic, compared carefully with those supplied by the various meteorological stations in Europe, point more and more to the truth of the old opinion that the Gulf Stream is the "parent of tempests" of the Atlantic and its coasts. Its comparatively high temperature, the abundant moisture of the air above it, the opposite winds blowing towards its course, all help to make it the theatre of frequent atmospheric perturbations. The aërial current which reigns above the Gulf Stream naturally flows towards the east, in the direction of Europe.

Besides these larger commotions that travel so far, it is now admitted that small *local cyclones* are occasionally formed in our latitudes, by the sudden combination of a northerly and southerly current. Such was the case in September 1876, when a minute storm of this description produced such havoc at Cowes, in the Isle of Wight. The author was at Bournemouth at the time and experienced nothing. Again, in 1878, a similar occurrence took place when the *Eurydice*

was lost in the English Channel. It may also be recalled that on the 25th and 26th October 1859, when the *Royal Charter* was lost, the gale appears to have commenced in the Bay of Biscay and terminated in the Baltic.

The whole question of cyclones is, however, far less simple than this brief sketch might lead my readers to suppose. It has been ably grappled with by Dove, of Berlin, who began his investigations as early as 1827, and his most recent work, the *Law of Storms*, embodies his views on this important subject.[1]

[1] *The Law of Storms*, by H. W. Dove, translated into English by Robert Scott, M.A. My copy of this important work was presented to me by the late Admiral Fitz-Roy, F.R.S., together with his interesting work, *The Weather Book, a manual of practical meteorology*, second edition, 1863.

CHAPTER XVII.

Absolute Weight of the Earth's Atmosphere—Various Optical Phenomena caused by the Air—The greatest height Man has reached on Foot — The Snow-line and Region of Perpetual Ice.

THE *absolute weight of the Atmosphere* is a very simple problem, though it has long been considered one of the most extraordinary achievements of modern science.

The mercury, in a barometer, standing at 30 inches, can be poured out of the tube into a balance and weighed. This weight is that of a column of air, of equal basis to the column of mercury. If the basis of the columu of mercury is equivalent, say, to one square inch, the weight of the metal in the tube will be about 15 lbs.

If we can find how many square inches cover the surface of the globe and multiply them by 15 lbs., the result will be the entire or *absolute weight of the Earth's atmosphere.*

In this manner a great astronomer and geographer (Francœur) found that the weight of the entire atmosphere, in tons, is represented by the figure: 523,260,000,000,000 tons.

We have already touched upon this subject when alluding, in a previous section, to the absolute amount of carbonic acid in the Earth's atmosphere.

The *various optical phenomena* presented by our atmosphere are so fully described in works on Physics, and Meteorology, that only a few words need be devoted here to this portion of our subject. As we have already said, the atmosphere is transparent and invisible, except when seen through an immense thickness; it is then blue, the colour of the pure sky. The presence of much moisture lightens this tint, so that it becomes grey. As we rise in the pure air, the vault of heaven becomes of a darker and darker blue, almost black, and the stars become visible, as they do when the sky is viewed from the bottom of a deep pit.

The average refraction of light passing through the entire thickness of the atmosphere causes the sun to be seen for eight minutes after it has set, and eight minutes before it actually rises, so prolonging our day by sixteen minutes at all seasons of the year. In some states of the air, refraction also distorts the figure of the sun near the horizon. It is not, as many have thought, the cause of the apparently increased size of the full moon near the horizon. This is an effect of contrast, caused by viewing the moon in comparison with objects on the Earth's surface; and if viewed through a narrow tube of cardboard, so as to shut out these objects, it appears of the same size as when seen at the zenith.

To refraction of light is also due, as we have already said, the curious phenomenon of the mirage, the prismatic colours of the rainbow, of the solar and lunar halos, and of the sky at sunset and sunrise. Another optical effect that used to be much talked about, is the so-called *Spectre of the Brocken*—that is, the magnified images of travellers standing at sunrise on the summits of the Hartz mountains, their shadows being thrown upon the mist or clouds by the rising sun at their backs. I have often seen this phenomenon *in the neighbourhood of London*, at night, when the light from a lamp upon a table at the back of the observer throws his magnified shadow through an open window upon a dense fog.

The electric glows, or *phosphorescence of rain-drops*, in thundery weather, which have been witnessed on several occasions at Geneva and other places, the light which sometimes issues from the summit of the masts of a vessel (*St. Elmo's fire*), or from the hats of pedestrians during a thunderstorm, the glow of the Aurora borealis, during which the magnetic needle is disturbed, and a number of other curious emissions of light, often connected with electric perturbations of the atmosphere, have been fully described by me in other works.[1]

[1] Phipson, *Familiar Letters on some Mysteries of Nature*, London, 1876; *Phosphorescence, or the Emission of Light by Minerals, Plants, and Animals*, London, 1862. (A spurious edition of this work was issued without the author's knowledge in 1870.) *Noctilucine* (pamphlet), London, 1875. "Phenomènes lumineux, etc.," *Comptes-rendus*, Paris, 1868.

The greatest height to which anyone has travelled on foot into the atmosphere, was that reached, some years ago, by the brothers (Herman, Adolph, and Robert) Schlagintweit, namely, 21,000 feet, on the 20th August 1856, on the Abi-Gumin, one of the highest summits of the Himalayas.[1] Their barometer stood there at about 15 inches; they had, therefore, only half the ordinary weight of the air to support (say 7½, instead of 15 lbs., to the square inch). Headache, difficulty of breathing, spitting of blood, irritation of the lungs, and great lassitude, were experienced. These symptoms gave way as soon as they reached lower ground. These travellers, like Dr. Kane in the Arctic regions, suffered less from the cold than from the wind; and they generally felt better in the morning than in the evening. Muscular action induced immense fatigue; even the act of speaking was fatiguing, and the lassitude was such that they could have fallen down and gone to sleep, for ever, upon the snow, had not supreme moral courage vanquished this great physical weakness.

Water, in the form of steam or vapour, which always exists to a certain amount in the atmosphere near the Earth's surface, is, as we said before, thrown out in the shape of cloud, or mist, as the air becomes colder. Now, as cold increases with the altitude, the vapour thus thrown out, and rendered visible where, before, it was invisible and only to be detected by our physical instruments, or by chemical analysis, assumes the form

[1] Some of our British troops have since been even higher than this, in the recent border warfare in North-Western India.

of snow or ice at a certain elevation on the slopes of high mountains. At a given altitude, which varies according to a multitude of circumstances, we come upon snow, or, as it is usually termed, *perpetual snow*, corresponding to the *perpetual ice* of the Arctic regions.

The term *snow-line* has been given to indicate the height which forms the *lower limit* on a mountain slope at which this phenomenon occurs. But this is *not a fixed line* at any given latitude, nor at any given point of the globe; it varies, by one to three thousand feet, according to the "climate" of the locality. But, in any region outside the Arctic zones, it is generally met with at altitudes exceeding 10,000 or 12,000 feet. On the volcano of Peuquenes (latitude 33° S.) it lies at about 15,000 feet; in the Himalayas at 12,000 to 13,000 feet; in Thibet at 16,000 feet, and so on.[1]

Alex. von Humboldt, who paid much attention to this subject, calls attention to the interesting fact that we are only acquainted with the *lower* (not the upper) limit of perpetual snow; for the mountains of the Earth do not attain to those higher regions of rarefied and dry air in which no water can possibly exist.

[1] See Humboldt, *Asie Centrale*, vol. iii., for table of height of perpetual snow in both hemispheres, from 71° N. to 58° S. lat.

CHAPTER XVIII.

The Formation of Clouds—The Vesicular Theory—The Present Theory—Cirrus Cloud—Cumulus Cloud—Stratus Cloud—Nimbus Cloud—Colour of Cloud and Sky as an Indication of Weather—Cause of Electric Phenomena in Thunderstorms—Formation of Snow and Hoar Frost—Formation of Hail—Curious Phenomenon of the "Cloud-arch"—First seen in England by the Author—Seen in Sicily by the poet Goethe—And in the Arctic Regions by Sabine.

THE formation of clouds and their various aspects have been the subject of a considerable amount of speculation. The vapour of water is colourless, and is transparent like the air in which it rises and diffuses: it rises, because it is lighter than air (air = 1000, vapour = 623). But if the air is a few degrees colder than the vapour, the latter at once becomes visible, and takes a certain form.[1]

[1] This sometimes occurs so suddenly that I remember, one evening, in Paris, the celebrated M. Babinet, member of the Institute and *Bureau des Longitudes*, who was a neighbour of mine, came to my rooms and brought me out on to the Place St. Sulpice to witness the variation in brightness of the star *Algol*, which is still a mystery to astronomers, when, just as we had succeeded in finding it, the sky became *suddenly overcast* with large mottled clouds, *over the whole heavens.* A clearing of the sky of equal rapidity is never witnessed, so that clouds can be formed by precipitation much more rapidly than

What then happens? Théodore de Saussure, and the older naturalists, asserted that the microscope solved this question; that the ingredients of clouds are minute vesicles of water filled with air, like the most minute soap bubbles it is possible to imagine. This was termed *vesicular vapour*; and when these little vesicles burst, they are converted into drops of rain.

Modern naturalists do not admit this "vesicular theory"; they contend that the water of the clouds is in the state of extremely minute drops which, when they coalesce, form larger drops that fall as rain. The minute drops remain suspended, just like certain powders, which are considerably heavier than water, will remain for a long time suspended in that liquid.

In the highest regions of the air these minute drops become frozen, and form tiny crystals of ice, which also remain suspended in the air for a length of time, as does volcanic dust, to which allusion has already been made.

The *cirrus* clouds, which appear like long wisps ("mares' tails"), at a great height in the air, are formed of these minute ice crystals. Although they usually *appear motionless to persons on the flat lowlands,* to those on the summit of a high mountain their movement becomes apparent, and they may be seen to *travel with considerable speed.* They are often six or seven

they can be dispersed by absorption or dissolution in the air. And this is *just what occurs in the chemical laboratory*, when a precipitate is formed instantaneously; but its re-dissolution is always much more gradual.

thousand yards high, and generally indicate a change of weather: their presence in the atmosphere, after several days of fine weather in Spring, Summer, or Autumn, announces rain within twenty-four hours; and this sign rarely fails. During the winter, if the weather be mild, they announce frost; but if cold, they indicate the approach of a thaw. The direction of their movement is often opposite to that of any clouds that may be seen beneath them.

The *cumulus* clouds are always lower; they appear at various heights, rising during the day as the heat of the sun increases. They make their appearance in Spring and Summer, and look like great bales of wool, or like mountains. When the sun shines on them, they resemble the snowy chains of the Alps, or the Pyrenees. When they disperse in the evening, it indicates a fine day for the morrow; but if they increase in size, or become more numerous at nightfall, and especially if cirrus cloud is seen above them, we may expect rain, or thunderstorms.

The *stratus* clouds form long, horizontal bands, often very wide, seen about sunset, and sometimes most gorgeously coloured. They disappear at sunrise, are common in Autumn, and rare in Spring (but they were very beautiful in London during the early part of April 1895). They rise less high than the two kinds of clouds previously mentioned.

Lastly, the *nimbus*, or rain-cloud, is usually of a uniform dark grey colour, and massive, though without any particular form.

These four divisions, not being sufficient for the classification of all forms of cloud, a few sub-divisions have been made, such as the *cirro-cumulus*, small rounded clouds spreading over a great portion of the sky, forming what is called "mackerel sky," or a "mottled sky." The French term is "*ciel moutonné*," as they often resemble a vast flock of sheep. They generally indicate fine weather, or heat.

The *cumulo-stratus* are cumulus clouds which have become more numerous towards the end of the day, and taken the character of the *nimbus*. They announce rain. *Cirro-stratus* are, also, often a sign of rain; they form long filaments, more closely packed than the ordinary stratus, and are not penetrated by the solar rays. Near the horizon they appear black, or bluish-grey.

If clouds are *white*, and the sky between *dark blue*, it is an indication that the drops of water are small, and that the air around the cloud is dry. There will be no rain. But if the clouds are *grey* and the intervals between them *dull*, or very light blue, the drops are larger, and the surrounding air damp. Rain will probably follow.

The cloud does not usually resolve itself into rain until the drops of water attain to a certain size. These drops are the cause of *coloured circles* (not *halos*) round the sun and moon. The smaller the drops, the wider is the diameter of the circle. *As the drops become larger the circle gets smaller*, and nearly touches the disc of the sun or moon. Rain is then near at hand; but wider circles often disperse without rain.

These coloured circles are more frequent than many believe; at night they are easily seen round the moon, but by day they can rarely be seen round the sun, unless the image of the latter be *viewed on a sheet of glass, one side of which is blackened by smoke from a lamp or candle.* On misty mornings it is often possible to say whether the day will be wet or fine, *by inspection of the width of the circle round the sun*; with drops that increase in size the circle gets smaller, and *vice versâ.*

The eminent Belgian meteorologist, Houzeau, says that *at the moment of condensation*, that is, when the invisible vapour is cooled down till it takes the form of minute drops of water, *electricity is abundantly produced.*

This evolution of electricity is the more sudden, the more rapid the condensation. Thus, when rain falls calmly, and clouds resolve themselves slowly, the electric phenomena are not very remarkable. But when the downpour is sudden, and the clouds are instantaneously transformed into a mass of water, the electricity has not sufficient time to disperse gradually, and there comes a clap of thunder. This explains why lightning in thunderstorms usually accompanies a sudden increase of rain. This sudden downpour is due to the mixing of two masses of air of different temperatures; it is the effect of *a sudden wind in the cloud region.* The result is a brisk condensation torrents of water are precipitated to the ground, and with them, torrents of electricity. Rain and lightning issue at the same time from the cloud, and if we usually observe that the downpour *follows* the lightning, it is

because a certain interval is required for the rain to reach the Earth, whilst the light of the electric flash reaches it instantaneously.

We can therefore admit this law, which is precisely in contradiction to common opinion, that *the electric phenomena of the atmosphere are the consequence and not the cause of thunderstorms.*

Ordinary rains do not differ from thunderstorm rains, except in degrees of intensity; both give birth to electricity—in the one case, almost imperceptible; in the other, terrible by its intensity.

The formation of *snow* from the vapour contained in the atmosphere, like that of *hoar frost*, is an example of crystallisation precisely similar to what occurs in the *sublimation* of benzoic acid, iodide of cyanogen, etc.; the nucleus of a crystal is formed by the fall of temperature, and the crystal rapidly *increased by contact of the vapour.* Snow is not exactly frozen water: when rain freezes, as I have sometimes witnessed, it forms *pear-shaped solid drops.* Crystals of snow and hoar frost are formed differently; they are the result of a true crystallisation, giving rise to exceedingly beautiful forms of the *hexagonal* type; whilst frozen rain, and ice generally, are the result of a sudden coagulation, a solidification in which crystalline structure is much mixed up, confused, and indistinct.

With a slight frost snow is abundant; it then falls in large flakes; but during long frosts snow is rare, the flakes are smaller. They end in forming tiny grains, a kind of *dust of snow*, such as was experienced during the

recent prolonged winter 1894–95. It is very rare, indeed, to have any fall of snow when the thermometer sinks to many degrees below freezing-point, to $-15°$ C. (5° Fahr.), for instance. At this very low temperature the quantity of vapour which the atmosphere can contain is not sufficient to form clouds of any size.[1]

The formation of *hail* is still an unsolved problem; it varies in size from the weight of a few grains to as much as nearly half-a-pound; the latter being, however, quite exceptional. It *precedes,* or accompanies storm rain, never follows it. It rarely lasts more than a *few minutes*; very rarely as long as a quarter of an hour. It is much rarer at night than in the *daytime.* I explain the fact of its dancing on the ground by its highly electrical state. It is quite possible to conceive that it may sometimes enclose solid particles which happen to be in suspension in the atmosphere, as in the singular observation of Baumhauer referred to in a preceding chapter.

Houzeau explains the phenomenon of hail by saying that if the drops of rain are formed in the higher warm current of air, or in some cloud heated by the sun's rays, and if they meet on their descent with a cold

[1] During a recent severe winter a number of persons were dining together in St. Petersburg. The room was very warm and contained much moisture from the steaming dishes and the breath of the persons present. One of the guests accidentally broke a window, which caused a stream of intensely cold air to flow into the apartment. In an instant, flakes of snow began to fall, and soon covered everybody in the room, just as if the guests had all been in a fall of snow out of doors. A similar occurrence has been previously observed, on several occasions, in the Arctic regions, at Nova Zembla, and in Siberia.

current, they arrive at the ground in a frozen condition as *hail*. This, he continues, is why hail "is most frequent in Spring"; the conditions for its formation being best fulfilled at that season. But the most severe hail is that which falls in Summer, during thunderstorms, and proves so disastrous to the crops in Central and Southern France.

Why it is more frequent in the daytime than at night, the same eminent writer says, is a question that applies also to thunderstorms: it is because sudden currents of air (which are termed in French, "*grains*," "*coups de vent*") are more common in the daytime. "They are due to the inequalities of temperature produced by the sun's rays on certain portions of the air, whilst other portions are in the shade."

If we admit Faye's theory (*Comptes-rendus*, 1895), the phenomenon of hail may be explained by assuming that it is due to the minute crystals of ice *sucked down from the higher regions of the air* into the vortex of the storm-cloud.

A few years ago I was witness in England of a most remarkable phenomenon, which I may call a *cloud-arch*, and the only observation of a similar kind that I have ever met with is contained in a few words inserted in the *Memoirs* of the poet Goethe, who witnessed it during his visit to Girgenti in Sicily. I will endeavour to describe, first, exactly what I saw.

We were travelling, my wife and I, from London to Bournemouth in August by a train which left London shortly after noon. We had not gone many miles into

the country before I noticed, in the far distance, a singular arch of light cloud, which lay about 20° above the horizon, exactly in the direction we were proceeding, that is, nearly due south-west of us. As we progressed on the journey the arch rose higher and higher above the horizon, so that in about two hours its summit approached the zenith of the spot where we then were, and beneath it was a pale, lavender-blue sky, quite devoid of cloud.

After awhile, when our train reached Ringwood junction, only a short distance from Bournemouth, *we passed right under the arch of cloud*, the summit being then at a great elevation in the atmosphere; and as we did so, we were sensible of having passed into quite a different climate; we had come, if I may so express it, from a season of *Spring*, into one of *Summer*. One of the feet of the arch appeared to rest on the land somewhere beyond Ringwood, and the other over the sea, on the Isle of Wight. This singular "cloud-arch" remained perfectly still, apparently, during the whole evening. Next day, I saw nothing of it.

This is what Goethe says of a similar observation in Sicily:

"*Girgenti, 27th April.*—Standing by the side of the sea, my attention was attracted by a long streak of cloud over the southern horizon, like an immense chain of mountains. These clouds indicated the African shores. Another phenomenon appeared to me still more singular; it was light cloud forming *a vast half circle*, leaning on one side on the soil of Sicily, rising boldly into a clear blue

sky, and bending down towards the position of the Island of Malta; and this half circle, I was told, often appeared in the air. Could it be a mysterious manifestation of the attractive force existing between these two islands?"

This quotation proves that the phenomenon was an unusual one to Goethe (who was a man accustomed to observe the phenomena of Nature), and, therefore, by no means common in our northern climates, though he was told it was often seen in Sicily. I find no description of this singular phenomenon in any work on Meteorology; but I have related in my little work on *Phosphorescence* (London, 1862) an account of an *auroral arch* witnessed by the late General Sabine in the Greenland seas, who kindly gave me a description of it, at the time he was President of the Royal Society. His vessel, the *Isabella*, sailing south, passed into one of the legs of the arch, at night, during which time everything on board the ship became visible by a diffused yellowish light, which was left behind as they proceeded on their voyage; the luminous arch then appearing in the distance, as it had done before they approached and entered one of the sides of it.

The two phenomena just related are difficult to explain in a few words; but, according to my experience, there is a marked difference of climate (if I may so express it) on each side of the arch.

CHAPTER XIX.

Influence of the Gulf Stream on the State of the Atmosphere over Europe and the Atlantic—The Curve of Average Temperature and its Teachings.

THE influence of the Gulf Stream upon the state of the atmosphere over Europe and the Atlantic Ocean has been vividly brought to light, more especially by the indefatigable labours of Maury. This immense current of warm water is referred to several causes, the principal of which is the tendency of the warm tropical waters to flow towards the poles, their high temperature making them lighter than the waters of the colder regions. The direction of the current is due, partly, to the rotation of the globe, which naturally deflects towards the east both the winds and the ocean currents.

Leaving the Gulf of Mexico, whence it derives its name, and passing the Straits of Florida, the Gulf Stream flows through the canal of the Bahamas, and pours itself into the Atlantic Ocean, where its waters preserve, for thousands of miles, their high temperature, and their direction towards the north. In the Gulf of Mexico this temperature is about 75° Fahr.; and when it merges into the Atlantic about 72° Fahr.—

some twelve degrees higher than that of the Ocean in the same latitude. When it has flowed over ten degrees of latitude, still further north, it has only lost about 4° of heat; and after a course of 3000 miles, in a northerly direction, it still preserves, even in the depth of winter, the mild temperature of summer.

Thus it arrives at the 40th parallel of north latitude, and then, spreading out, it covers many thousands of square miles, bestowing upon this vast surface its congenial warmth. Meeting with the banks of Newfoundland, where it gives rise to dense fogs which are so dangerous to navigation in winter, it deviates towards the east, and continues its course with less impetuosity, until it reaches the British Isles. There it divides into two branches, one continuing towards the north to the polar basin of Spitzbergen, whilst the other, flowing down the English coasts, throws itself into the Gulf of Gascony, both branches preserving a temperature several degrees higher than the ocean.[1] Its influence on the Orkney Islands is such that although situated at 60° north latitude, ponds rarely freeze in winter, and the climate of Liverpool, for instance, which is more northerly than Newfoundland, is quite mild and agreeable; whilst Labrador, which corresponds to England on the American coast, is almost uninhabitable. If the temperature and velocity of the Gulf Stream were the same at 200 fathoms as at the surface, the quantity of heat evolved from its waters into the

[1] Ships that are covered with snow and icicles experience the effects of a rapid thaw the moment they enter the waters of the Gulf Stream.

Atlantic would, according to Maury, suffice to raise from freezing-point to summer temperature the entire bulk of the atmosphere lying over Great Britain and France.

Most of the atmospheric perturbations of the Atlantic Ocean can be traced to the influence of the Gulf Stream. Not only the fogs of Newfoundland, but the disastrous tempests of wind, or hurricanes, which occasionally blow in certain parts of the Atlantic, appear to be due to the difference of temperature between the waters of this vast current and those which surround it. Storms have been traced from the west coast of Africa and followed across the ocean until they meet with the waters of the Gulf Stream, when, instead of continuing their straight course, they suddenly change their direction, and blow again across the Atlantic, till they reach the coasts of Europe, marking their trajectory by a series of calamities.

The mild climate of the British Isles is very greatly due to this immense current of warm water, without which we should be no better off, in this respect, than people who live in the Arctic circle.

There can be little doubt that, as there exist in the Earth's atmosphere, fluctuations of temperature, of electricity, of barometric pressure, and of magnetic force, this vast stream of warm water may, also, have its periodical fluctuations of quantity, or temperature, and I am of opinion that it may thus affect what is known as the *curve of average temperature.*

After a careful consideration of this curve of average

temperature in our climate, for every day of the year for forty years, I find that, in any given month of the year, this line tends to rise in a very marked manner from the 10th to the 25th of each month. The only remarkable exception to this law is during the few cold days about the 12th May, which, as I have previously hinted, are probably due to the absorption of atmospheric heat by the melting of the winter snows and icebergs, and to the position of the belt of November meteors, which, at that period, is between us and the sun.

CHAPTER XX.

Aërolites, or Stones from the Air—"Thunderbolts"—A Stroke of Lightning—A Fall of Meteoric Stones—Belt of Meteorites round the Earth — Shooting-star Orbits and Comets — Old Opinion of the Indefinite Extension of the Earth's Atmosphere.

THERE was a time, not so far distant from us, when *aërolites*—stones from the air—were supposed to be formed in the atmosphere of the Earth, from the exhalations of the soil becoming condensed in the higher regions, and then falling heavily to the ground.

The phenomena which accompany these falls of aërolites, of which one, at least, occurs every year upon some part of the Earth's surface, are so similar to what is observed when lightning strikes any object, that they were once called "thunderbolts"; and as aërolites always contain more or less sulphur, the common rolled pyrites (sulphide of iron), found on the sea-shore, also got this appellation of "thunderbolts," and these rounded stones of common mundic, were often put away in collections as "aërolites," or "meteorites"—that is, stones which have fallen from the sky.

When lightning strikes an object on the Earth's

surface (as it did on the 17th April 1895, at about 4 p.m., between Putney and Barnes, a few yards from where I stood), the effect is like that of a large piece of artillery. The light and sound are instantaneous; a ball of vivid red light, about the size of a child's head, shoots from the sky to the earth with greater rapidity than a ball from the mouth of a gun, and the single report of the explosion is coincident with the flash.

In the case of a fall of aërolites, the noise occurs like a rumbling of loud thunder, which is heard only some considerable time after the fall of the stones. There is also a peculiar metallic ring in the thunder of the aërolite; but I have heard that, also, when lightning strikes, as it did in July 1894, a short distance from where it fell on the 17th April 1895, as just mentioned. It is like the shaking of huge chains. I have heard it on some other occasions also; so that the *metallic sound* may occur in both cases.

The lightning stroke leaves nothing behind it save a slight mist, an odour of sulphurous vapour, and its peculiar effects on trees, animals, or houses, etc. In many cases, houses have been struck by lightning, and the inmates have experienced nothing but alarm from the noise, little or no traces of any effects being afterwards found. After a fall of aërolites the stones are found either on the ground or buried a few feet below the surface.

In my volume on *Meteors, Aërolites, and Falling Stars*, published in 1867, I have given a complete history of these phenomena, and their distinctive character-

istics. I have there given the chemical composition of all the principal aërolites which have been picked up shortly after they were seen to fall, and then submitted to analysis; also, a classification of the three kinds according to the amount of *metallic iron* they contain.

This amount may vary from less than 1 per cent., to 98 or 99 per cent., the rest consisting of silicates and sulphides, but it is always present, and it always contains some *nickel* (another magnetic metal, like iron).

In the work just mentioned, I have also given a theory of my own with regard to the *origin of aërolites*, namely, that they form a ring of minute satellites around the Earth, like the ring of Saturn—which is now, also, being found to consist of a vast number of minute satellites, and so far confirms my theory of 1867.

At certain intervals, the position of the Earth in its orbit is such with regard to other planetary bodies, that some fragments from this dark ring are attracted to its surface, and crash through the atmosphere as "*fire-ball meteors*," which explode with violence, and shower down stones, or metallic fragments of various sizes—from that of a walnut or less, to that of a man's head; or, even, far greater than this, if the immense masses of iron found in Australia (now in the British Museum), and at Ovifak, Greenland, are really aërolites.

These falls of stones from the atmosphere have been observed for some hundreds of years before Christ, down to the present time. Formerly, they were

thought to be shot from volcanoes in the Moon. They are, no doubt, of the same chemical composition as the Moon; and are, I believe, minute satellites of our Earth, thrown off like our larger satellite was thrown off, in the earliest ages of its existence.

That is, perhaps, a better theory than supposing them to be shot out from our terrestrial volcanoes in activity at the present time.

Shooting-stars are quite different. Formerly, they were thought to be the same phenomenon as bolides, or aërolites: and I myself classed them all in one category, which a learned writer in the *Saturday Review* thought rather premature—and he was right. Since the discovery made by the Italian astronomer, Schiaparelli (made known *since my work on Meteors was published*), that the swarms of shooting-stars which arrive in our atmosphere at certain stated intervals, present the same orbits as comets, these two classes of natural phenomena (comets and shooting-stars) are believed to be one and the same. Before Schiaparelli's time, Reichenbach held a similar opinion.

This is what I wrote on *aërolites* in 1867: "Taking especially into consideration the chemical composition of aërolites, we may be tempted to suppose that these meteoroids have orbits *round the Earth*, not round the sun, and that they constitute a series of dark rings around our globe, similar, perhaps, to the rings of Saturn." (*Meteors, etc., loc. cit.*)

This quotation is interesting now that Professor Keeler, and others, are endeavouring to prove *that*

Saturn's ring is composed of small asteroids (meteoroids, aërolites).

There was also a time, not yet more than a century or so removed from us, when many philosophers held that the Earth's atmosphere extended indefinitely around the globe, becoming more and more rarefied—the *density* decreasing in geometrical ratio, whilst the *distance* from the surface increased in arithmetical ratio, according to the celebrated Halley—until it blended with the rarefied atmospheres of other planets. But when it was found that no atmosphere of any kind could be detected around the Moon, this theory began to give way; and it was supposed, henceforward, that the Earth's atmosphere, whether it extended to 50 or to 500 miles, was limited; that it participated in the diurnal and annual movements of the globe, and was held to the Earth by gravitation, just as a pebble on a garden walk. But just as the pebble may, under the influence of the spade or rake of the gardener, have its own independent motions, so our atmosphere, under that of the Sun's rays, is in a constant state of change and activity.

CHAPTER XXI.

The Organic Matter of the Atmosphere—Effluvia, Miasma, Malaria, etc.

THE *organic matter* contained in the Earth's atmosphere has been touched upon in several previous sections of this little work, but a few more observations are requisite to complete our notions upon this important subject.

When a current of atmospheric air is passed, for a certain length of time, into pure sulphuric acid, this liquid, which is originally as white and transparent as water, becomes more and more coloured, and finally dark brown. The quantity of air thus passed, before the brown colour is obtained, supplies some indication of the absolute amount of organic matter present in the atmosphere of a given locality at the time the experiment is made.

This organic matter has been found to consist chiefly of microscopic cells, quite invisible, and not affecting to any great extent the transparency of the air. These cells are brought down in large quantities by snow and rain; they can be filtered from the air by passing it through cotton wool, as two German chemists, Schroeder

and Dusch, showed many years ago; and they are *completely destroyed by fire*, which is *the most effective of all disinfectants.*

These microscopic cells are constantly present in the atmosphere in all parts of the globe, to a greater or less extent, according to circumstances; they are organized beings which play an important part in the economy of Nature. Before they had been scrutinized by the scientific methods of modern times, their existence had long been suspected; and they have been successively alluded to as *effluvia, malaria, miasma, bacteria, microbes, germs of disease, ferments,* etc. They are extremely numerous, and varied, infinitesimally minute, and are the promoters of fermentation, decay, and diseases of all kinds, both in animals and plants; at the same time, they contribute to the fertility of the soil, and the purification of air and water, thereby promoting health and vitality.

One of the greatest achievements of the science of the nineteenth century is to have brought to light the nature of what the old naturalists and physicians used to speak of vaguely as *miasma* and *virus.* The successive experiments and observations of Schwann of Berlin in 1837 (who *calcined* his air), followed by those of Schultze, who *passed the atmospheric air through sulphuric acid*, and found it incapable of producing life in organic liquids which had been boiled, whilst air *not so treated allowed the production of algæ and infusoria* of all kinds; of Schroeder and Dusch (in 1854 and 1859), who *filtered air through cotton wool,* and found

it, also, incapable of promoting the decomposition of sterilized beef-broth, the cotton wool having retained the germs; and finally, the observations of Dr. Davaine (1856), and M. Pasteur (1859), have brought this branch of knowledge to a great degree of perfection. At the present time hundreds of investigators are following up the researches of these clever observers in all parts of the civilized world.

When water is boiled for some time, these microscopic organisms which, like the air, it always contains, are destroyed. The water is then "sterilized," as it is termed, and no life can be detected in it. But by exposing it for a certain time to the atmosphere, and to sunlight, *green matter* is seen to form in it: *microscopic plants*, the germs of which have fallen from the air, develop in it rapidly, and are soon buoyed up to the surface of the liquid by the bubbles of oxygen gas which they secrete.

The ease with which the germs of these extremely minute organisms are dispersed through the atmosphere became very apparent in one of my recent experiments; a few bubbles of carbonic acid gas having been passed into a long tube nearly full of nitrogen, through water in which this green matter had developed, I noticed in a few weeks some excessively minute specks at the very top of the tube, a foot and a half from the surface of the water. In time, these tiny specks turned green and increased in size; they were found to be *algæ*, identical with those in the water below. *Their germs had been carried up through the nitrogen gas, and had*

developed on the moist sides of the tube, near its upper extremity.

All these minute mono-cellular organisms, which are quite invisible in the air, have always played a most important part in Nature, from the earliest geological ages of our globe to the present time. They were, as I have shown, *the first producers of free oxygen gas in the atmosphere of the Earth, by which, alone, animal life became possible.* They are the cause of biological phenomena of all kinds, by which the Earth retains its fertility. They multiply with the most astonishing rapidity, which compensates for their minute size and short cycle of existence. They are the first principles of life, and of vital activity in health and disease.

These *microbes*, as they are now often called, have been classed into two categories—those which appear to be harmless, and those which give rise to disease in plants and animals. But this classification is very arbitrary. Certain kinds appear to be present in greater numbers in times of epidemics; and it is generally supposed that epidemics of measles, scarlatina, diphtheria, small-pox, cholera, influenza, typhoid fever, etc., are due to the prevalence, at certain times, and in certain localities, of the special microbes of these various maladies. However that may be, it is quite clear that *the whole population of a district is not attacked at once*, and that, in the most virulent of epidemics, a great number, we may say by far *the greatest number of people, are never affected at all*, though they must all have been penetrated with the microbes in the same manner as

those who were affected. This shows that it is only in the blood and tissues of persons who are more or less delicate that the microbes of the atmosphere find a soil suited to their development, and that on persons in tolerably perfect health they have no effect at all.

For more ample details on this important subject, I must refer to my *History of Bacteria*, which appeared in the early numbers of my medical journal.[1] The *cause* of disease must be looked for beyond bacteria.

[1] Phipson, "A History of Bacteria," and "Supplements to a History of Bacteria," in *Journ. of Med.*, etc., London, 1880–1894. See also my *Health Notes and Curiosities of Medical Science*, London, Routledge, 1898, one vol.

CHAPTER XXII.

State of the Atmosphere in any given Locality—Immediate Weather—Table for British Isles and Northern Europe generally—Rainfall.

From a practical point of view, the instruments which are the most useful in supplying data regarding the *state of the atmosphere in any given locality* are the barometer and thermometer.

Before the present system of *telegraphing the weather to be expected* in any particular quarter was put into practice, it was quite possible, by a careful observation of these two instruments, to foretell by about twenty-four hours what kind of weather was coming. But such observations were rarely made; few seaports were properly provided with these instruments, and their indications were nowhere precisely understood.

I have already mentioned several important indications supplied by the barometer and thermometer; and I will now add a few practical details as regards the *immediate weather* of any given locality—that is, the weather that may be expected in the next twenty-four hours—as it can be foreseen by scrutinizing the movements of the mercury in the barometer, the direction of

the wind at the time of observation, and the aspect presented by the sky.

Fitz-Roy has laid down the rules for the barometer in a very clear manner.[1] It *rises* in our north latitudes for *cold, northerly* (N., N.E., N.W.) winds, *less wind,* and *dry air*; and it *falls* for *warm, southerly* (S., S.E., S.W.) winds, for *more wind,* and *wet,* the only exception apparently being, occasionally, with wet from the north-east (when it remains high). In the Southern hemisphere the words "south, southerly," etc. must be substituted for "north, northerly," etc.

The barometer expresses *the connection of the present wind with that which is about to blow*; and this alone is sufficient to render its indications of very great service to us.

Such being the case, I will give here a little *table,* the indications of which are the results of long experience, feeling certain that it will prove extremely useful.

The first thing to be done is to ascertain the direction of the wind by observation of the weathercock, or, better still, by the direction of the lower clouds. Then, we must observe with care the state of the barometer and the thermometer. It will be best to make these observations *always at the same hour,* say between nine and ten in the morning, regularly.

Here is the little table in question: it applies to the British Isles, Belgium, Germany, France, and northern Europe generally.

[1] Fitz-Roy, *The Weather Book,* second edition, p. 10.

IMMEDIATE WEATHER.

Direction of wind.	State of the barometer.	State of the sky.	Weather to be expected.
N.	Rising.	Clear sky.	Cold and dry weather.
		Cloudy sky.	The sky clears.
		Rain or snow.	Wind passes to N.E.; showers and sunshine.
		After a gale.	Air cools and remains fine, then gets warmer by the sunshine.
	Falling.	...	Clouds rise, weather gets warmer for a time.
N.E.	Rising.	...	Cold rain, or snow.
	Steady.	Clear sky.	The wind continues; dry weather established.
		Cloudy sky, with rain or snow at the commencement of the N.E. wind.	Wind continues; fine weather returns.
	Falling.	Fine; small mottled clouds, very high.	Heat, without rain.
		Fine; slight haze over the sky, stars pale.	Rain in summer, thaw in winter.
		Showers at intervals.	Wind passes to E. or S.; the sky gets covered with small round clouds, or becomes quite fine.
	Falling rapidly.	Continuous and rigorous cold, apparition of white haze over the sky.	Fall of freezing rain: "silver thaw," soon followed by milder weather.
		Overcast.	Wind goes S.E. or S.; sky clears; cold is intenee, then cloudy and thaw within 24 hours.

IMMEDIATE WEATHER—*continued.*

Direction of wind.	State of the barometer.	State of the sky.	Weather to be expected.
E.	Rising.	...	Cold rain, or snow, according to the season.
	Steady.	Fine	Wind persists; dry weather lasts.
		Cloudy, after rain or snow.	The wind persists; sky gets fine.
	Falling.	Fine, little light clouds.	Heat, without rain.
		Overcast or cloudy.	Rain.
		Heat continuing after rain.	More rain.
		Snow.	Turns to rain; milder weather.
	Falling rapidly.	Fine.	Tempest of wind from the S.; sometimes accompanied by thunderstorm.
		Overcast.	Wind passes suddenly to S.; sky clears; air gets dryer for several days.
S.E.	Rising.	...	Cloudy sky, passing showers.
	Falling.	...	Clouds increase; wet weather generally comes on soon.
S.	Rising.	...	Fine weather; rarely durable.
	Falling.	Fine.	Clouds form; weather changes.
		Cloudy.	Clouds increase; rain.
		After a gale.	Close, rainy weather.
	Falling rapidly.	...	Storm of wind, especially in winter, and generally when the thermometer is very high for the season.

IMMEDIATE WEATHER—*continued.*

Direction of wind.	State of the barometer.	State of the sky.	Weather to be expected.
S.W.	Rising very quickly.	...	Wind soon goes to N.E. Prolonged cold; especially in spring.
	Rising.	Variable and uncertain weather.	Rain almost certain.
		Fine rain, low clouds.	Wind goes W.; clouds increase, heavy rain; air colder.
		Violent wind (gale).	As soon as the barometer begins to rise, the wind passes in a few hours to N.W., still strong and then N.E. with cold.
	Rising slowly after being very low.	...	Wind goes to N.W. and remains there. We may expect westerly winds for the rest of the season.
	Falling.	Warm weather after westerly rains.	Wind soon goes round with rain.
	Falling very low and for a long time.	...	Persistent rain.
W.	Rising rapidly.	...	N. winds of short duration. Wind goes again S.W. and the barometer falls again; generally not so low as before.
	Rising.	With falling thermometer.	Rain almost certain.
		Without an immediate fall of the thermometer.	E. or N.E. wind; sky charged with cloud; rain, snow, or fog. But the weather gets fine, and cold if E. wind continues.
		Rain.	The thermometer falls; wind goes N.W.; rain persists, and in winter becomes snow.

IMMEDIATE WEATHER—*continued.*

Direction of wind.	State of the barometer.	State of the sky.	Weather to be expected.
W.	Rising.	Snow.	Cold. If the N.W. wind brings more snow the cold increases and becomes severe.
	Rising slowly.	...	Constancy of N. winds.
	Oscillating.	...	Scuddy, changeable weather.
	Falling.	...	Weather gets warmer; rarely rain is immediate, but falls as the rotation of the wind is re-established.
	Falling very low.	Abundant rain.	Gale from the S.W.
N.W.	Rising.	Uncertain, or fine weather.	Clear sky, cold.
		Rain or snow.	Wind goes N. or N.E.; showers and sunshine; blue sky between the showers.
		Snow, after other snow from W.	Cold; which will be severe.
		Wind very strong after a gale, thermometer falling briskly.	Cold; wind goes N.E.
	Falling.	...	Milder interval without rain, until the barometer rises and the wind goes round; at this moment rain falls.

This table, which was drawn up by Houzeau, first assistant to the celebrated Quetelet, director of the Brussels Observatory, has been tested by me on many occasions in Belgium, France, and Great Britain; it has proved generally correct for the first two countries, and

tolerably so for England, where the weather is more changeable, and at the same time more temperate, than in other parts of Europe. Nevertheless, it is only an indication of probable results; it contains nothing absolutely certain.

It is now almost a century since our great English meteorologist, Howard, turned his attention to the amount of rain which falls in a given locality and at a given season. Speaking of England, some have said that *April* is the driest month, and *October* the wettest; but Fitz-Roy says *March* and *July*.

Howard showed, long ago, that the quantity of rain which falls in London in one year is very variable: In 1802 he found 14 inches; in 1810, 27½; and in 1816, 32 inches.

Symons puts the *mean* rainfall *per annum* for London at *25 inches*, and for all England at 31 inches. The proportion for the various seasons is roughly stated as: Winter 5·8; Spring 4·8; Summer 6·7; Autumn 7·4; total = 24·8 inches. But *averages* (or means) are only useful for comparison. Engineers require to know the *extremes*; for these are what are actually experienced, and what we have to deal with in practice. For instance, more rain may fall in an hour than is due to one month, according to averages. If the flow of water in our rivers during a dry season is taken as *unity* (*one* volume), the volume in wet weather is generally 300, and in extreme cases 500. A river in England may rise, from floods caused by rain, as much as 23 vertical feet; and in South Africa, and America,

etc., as much as 60 or 70 feet. As regards waterworks, we must know the *minimum*; for bridges, culverts, and embankments, the *maximum* of water which the atmosphere will yield in a given locality.

It is not generally known that the rainfall of all towns in Great Britain is more than sufficient, if it were collected, to supply all the wants of their inhabitants as far as water is concerned.

CHAPTER XXIII.

Fogs and Electricity — Ronayne's Discovery — Luminous Fogs—Prevention of Thunderstorms and Hail.

THOUSANDS of tons of water are evaporated daily from the waters of the ocean by the heat of the sun's rays; this water rises as vapour into the air, forms clouds, fogs, and dew; falls again as rain, produces springs, streams, and rivers, which flow to the sea, and whilst protecting the surface of the Earth from the effects of undue radiation, gives to the soil that degree of moisture which is essential to life and fertility.

Fogs, in the days of Sir Humphry Davy, were thought to be always due to the cooling of the air lying over water; and, no doubt, a mist is often formed from this cause; but that is not invariably the case. George Harvey, in 1823, contradicted Davy's statement, and showed that fogs were sometimes formed when the temperature of the air on the land is *higher* than that of the water and the air above it, in which the fog exists. As early as 1814—five years before Davy's observation—Thomas Young showed, on the occasion of a remarkable fog which lasted from 27th December 1813 to 23rd January 1814, in London, the tempera-

ture varying during this period from 21° to 34° Fahr., that difference of temperature between the air and the water could not explain such a phenomenon.

The fact is, that electricity plays a great part in the production and duration of fogs. An English observer, Thomas Ronayne, first discovered (in 1761) that *fogs are highly electrical*, quite as much so as clouds. His observations were published in the *Philosophical Transactions*, but attracted no attention till they were repeated in 1774 by Henley. In more recent times, much attention has been given to the subject by Peltier, a Belgian observer.[1]

The Earth being always electro-negative, the fogs are sometimes electro-positive, and sometimes electro-negative. In the latter case, being repelled by the soil, they *do not wet the Earth's surface*. But there exists a rare kind of *electro-positive* fog which does not wet the ground either. Such was, for instance, the celebrated *dry fog* of 1783, which made its appearance at about the same time in many distant places, spreading from North Africa to Sweden. It exhaled a disagreeable odour, was remarkably dry (not affecting the hygrometer at all), and was decidedly luminous at night; sufficiently so to enable a person to see objects at a distance of 600 feet; and it lasted about a month.

Fogs are often so electrical that they diffuse much light at night.[2] A remarkable instance of this was

[1] Peltier, *Mémoire sur les diverses éspèce de Brouillard*, Bruxelles, 1842.

[2] Phipson, *Phosphorescence*, etc., London, 1862; and *Familiar*

noticed by Professor Wartmann, of Geneva (18th to 26th November 1859). The moon, being new, was invisible, but a vast fog, not damp enough to wet the Earth, but so opaque as to render invisible the borders of the river Leman and the Mont Salèze, lay over Geneva and its environs. It diffused so much light, that a person walking from Annemassa, in Savoy, on the 22nd November, saw his way as clearly as if it had been a moonlight night. Auguste de la Rive, the well-known electrician, made a similar observation about the same time.

In 1863, Dr. Meissner, of Göttingen,[1] showed that moist air submitted to the action of electricity in closed tubes produced a mist, which did not disperse on being passed through water, but appeared again on the surface of the water, and lasted about half an hour, after which it gradually disappeared, depositing dew on the sides of the glass vessel.

It is probable that if a few high towers, surmounted by very long metallic rods communicating properly with the Earth, were erected around our large cities, the latter would be rarely or ever troubled by thunderstorms. Such an arrangement would likewise prove very beneficial in the wine districts of France, in such places, for instance, as the little town of Tonnerre (ominous name !), where thunderstorms, with hail, cause so much destruction to crops and property. It has been

Letters, London, 1876. Peltier, *Memoirs of the Acad. of Sc.*, Bruxelles, 1842.

[1] Meissner, *Untersuch. über den Sauerstoff*, Hanover, 1863.

recorded that the late Professor Charles, a well-known French scientist and aëronaut, more than once succeeded in arresting the progress of a thunderstorm, which was approaching Paris, by sending up an immense kite with a metallic string. When I resided in Paris, before the Franco-German war, the wooden stand to which this kite was attached was still preserved at the *Conservatoire des Arts et Métiers*; the wood appeared to have been thoroughly calcined by the numerous electric discharges that had fallen upon it from the atmosphere. Dr. Lining, of Charlestown, U.S., and De Romas, of Nérac, in France, seem to have entertained no doubt on this subject; and once François Arago said that he believed the problem of *transforming thunder-clouds into ordinary clouds* had been solved. It is admitted that, by subtracting their electricity, thunder-clouds can be prevented from forming hail; and if this be really the case, it would be most important to establish in certain districts a catching agency of captive balloons, kites, or towers with metallic rods, communicating with a water-course, or with the moist soil; for not a year passes but hail does great damage at such places as Rieux, Comminge, Lombez, Tonnerre, etc. Some time ago I saw an official report that showed damage to crops amounting to *one million pounds* English money, after *a single thunderstorm* in France.

The kite which M. De Romas flew at Nérac, the string of which was surrounded by fine copper wire, effectually subtracted electricity from the storm-clouds; and whilst these experiments lasted, no lightning was

seen, nor thunder heard. Yet this kite only rose about *160 yards into the atmosphere*; and in presence of comparatively small thunder-clouds, he drew from the string flashes of lightning from 7 to 10 feet in length. In less than an hour he got as many as thirty of such flashes.

CHAPTER XXIV.

Atmospheric Tides—Magnetic Storms—Sabine's Observations—Absorption of the Moon's Atmosphere.

THE attraction of the Sun and Moon upon the waters of the Earth, giving rise to the phenomenon of tides, it is evident that *atmospheric tides* must be produced in the same manner, and affect the weather to some extent. But no exact laws in this respect have yet been established, and it is impossible to refer change of weather, in any given locality, to the influence of the Sun and Moon upon the atmosphere. Popular notions on the effects of a "change of moon" upon the weather are not borne out by scientific observations.[1]

In reading the works of Maury, a modern scientific observer cannot fail to be struck with the immense amount of work which still requires to be done with regard to the origin or cause, and even as to *the directions* of the various currents of the ocean and the atmosphere. His writings bristle with hypotheses

[1] See on this subject P. Garrigou-Lagrange, "Rélations entre les mouvements barométriques et les mouvements en déclinaison du Soleil et de la Lune" (in the *Comptes-rendus* of the Paris Academy of Sciences, 11th February 1895, p. 342). See also a note by another author in the *Comptes-rendus* for the 10th February 1896.

which observation has not yet confirmed, though he has given us a considerable amount of useful experience. Nevertheless, his notion of the *cloud-ring of the equatorial regions*, which he likens to the ring of Saturn, his belief in a current of air that reaches us from South America, carrying *red dust*, in which Ehrenberg found the same kinds of infusoria in whatever part of the globe this red dust was collected, the statement that the *magnetic condition of the Earth* may produce a retardation in the progress of winds, and many other haphazard statements, where imagination plays a much larger part than direct experiment or observation, must not be allowed to mislead us in the calm investigation of Nature's mysteries. Humboldt is one of the few observers who have never allowed hypothesis to take too large a place in his writings; and, at the present day, the patient labours of the scientific expeditions, like that of the *Challenger*, or even the more modest work of the Prince of Monaco and the late Georges Pouchet, will, in after years, enable us to reap far finer practical results than can ever be expected of mere theory.

We have yet said little of the *magnetic condition of the atmosphere*, the most difficult, complicated, and least known of all its phenomena.

The wonderful discovery made by Faraday of the *paramagnetic property of oxygen gas*, showing that it takes polarity by the action of a magnet, just as iron does, can have little or nothing to do with the beautiful phenomenon of the Aurora borealis and australis, which must have existed long before free oxygen gas

existed in the Earth's atmosphere, that is to say, long before the advent of plant life.

During the Aurora the magnetic needle is affected very powerfully, just as an ordinary electric current affects it. The so-called *magnetic storms*, which occasionally interfere with the working of the electric telegraphs in all parts of the world, mostly come on *without any previous warning*, as we observe to be the case with earthquakes. It is not yet certain whether these magnetic storms are connected solely with the gaseous envelope of our planet, with the Earth's solid crust, or with some region underneath this crust.

The observations of Sabine[1] have shown conclusively that the periodic variations of the magnetic activity of the Earth cannot be based on periodic changes of temperature in those parts of the atmosphere which are accessible to us. Nor do the epochs of these periods coincide with the *maxima* and *minima* of the temperature of the atmosphere. Nevertheless, the influence of the Sun's position upon the manifestation of the magnetic force of the Earth was known at a very early period. Kepler discovered the horary variation of the magnetic needle, and believed that all the axes of the planets were magnetically directed towards one portion of the Universe; he thought that the Sun may be a magnetic body, and, on that account, the force which impels the planets may be centred in the Sun. Horrebow in 1730, who did not confound gravitation and magnetic attraction, thought that light was the

[1] *Phil. Trans.*, 1850.

effect of a perpetual aurora produced in the Sun's atmosphere.

In both hemispheres, the epoch at which the intensity of the terrestrial magnetic force (whether in the atmosphere or elsewhere) is *greatest*, is identical with the period at which the Earth is *nearest to the Sun*, and consequently when its velocity of translation is greatest.

Whether magnetism increases as we rise in the atmosphere is a disputed question of minor importance, since the great currents of the air keep its temperature and electric condition in a constant state of change, though its chemical composition remains apparently constant. When the electric current, to which the Earth's magnetism may possibly be due, is caused to flow through very rarefied air, it gives rise, as everyone knows, to appearances similar to those of the Aurora.

Humboldt observes that "it would be inconceivable if, amid the harmonious co-operation of all the forces of Nature, the paramagnetic property of oxygen gas and its modifications by an increase of temperature should not participate in the production and manifestation of magnetic phenomena." But all this is mere suggestion; and it is far more probable that magnetic phenomena occurred, as I have already intimated, before any free oxygen existed in the atmosphere. It is certainly a singular fact that oxygen, hitherto, is the *only gas* which has been found to be *paramagnetic*.

The atmosphere is not only an essential medium for the life of man, but for the life of the entire globe. No manifestation of life on the Earth would be apparent

if there were no atmosphere; and should it be finally proved that our satellite, the Moon, is quite devoid of an atmosphere, it must be considered as *a dead globe*, like the meteorites, which in all probability circulate also round the Earth. But, strange to say, traces of organic matter, which may or may not have been derived from organized beings, have been discovered in meteorites.

Some believe that the Moon once had an atmosphere like that of the Earth, but that it has been absorbed.

What would happen if the Earth's atmosphere were to be absorbed is too dreadful to contemplate. The whole life of the globe depends upon it; and we could conceive nothing more desolate, cold, soundless, dark, and *dead* than the Earth deprived of its essential envelope.

APPENDIX A.

I.—Account of an Experiment made with *Convolvulus arvensis* vegetating in an Atmosphere devoid of Oxygen.

In addition to the experimental notes I have already published to demonstrate the truth of my new theory as to *the origin of atmospheric oxygen*, I give here the details of an experiment made with *Convolvulus arvensis*, a plant which I have often used for this purpose, vegetating in an atmosphere quite devoid of free oxygen, whilst two other plants of the same species were growing alongside of the apparatus as "witnesses," in ordinary atmospheric air. This is one of the experiments which first showed me that the plants of our present epoch are truly *anaërobic*, like those of former geological periods, and that free oxygen in the air is not essential for their existence.

This experiment with *Convolvulus arvensis*, vegetating in what may be termed a "primitive atmosphere," is typical of what occurs with all the phanerogamic plants previously mentioned, and with the green unicellular algæ such as *Protococcus palustris* and the minute *Microcystis* or *Chalmidomonas*, etc., which develop in spring water exposed for some weeks to the light.

The nitrogen was obtained from pure sulphate of ammonia,

or by the action of potash and pyrogallol on atmospheric air. It will be seen by what follows that *the same volume of nitrogen* may be used over and over again, as it undergoes no alteration in volume or properties, except such as are due to oscillations of temperature and pressure.

The apparatus consists of a graduated tube, wide enough to admit the plant easily, standing over water containing minute quantities of all the substances known (or supposed) to be necessary to vegetation, and kept supplied with carbonic acid.

Alongside the graduated tube stands a smaller tube full of water. Into this smaller tube carbonic acid is introduced, at first once a day; it displaces the water; but in the course of twenty-four hours the water has absorbed this gas, and the tube is again full of water.

Carbonic acid is again passed into it next day, and the water displaced, now saturated with carbonic acid, thus finds its way to the roots of the plant. In this manner the water of the basin in which stand the two tubes is kept supplied with an appropriate quantity of carbonic acid.

The whole apparatus is exposed to a constant northern light, such as is used by artists, which I have found preferable to a southern aspect, or to the direct rays of the sun.

The temperature of the laboratory whilst this experiment was carried out varied from about 60° to 90° Fahr.

One-half of the water in the little basin is covered with a piece of plank, to procure darkness for the roots, and a certain amount of carbonic acid is let into the wide graduated tube from time to time.

In this "primitive atmosphere" of nitrogen, containing some carbonic acid, and vapour of water, vegetation is found to be tolerably prosperous, *in spite of the confined condition of the air*: the carbonic acid is absorbed and replaced by free oxygen, so that after a certain lapse of time the gas in the graduated tube approaches the composition of ordinary atmospheric air, and can even be made richer in oxygen than the latter.

First 75 cubic centimetres of pure nitrogen (reduced to 0° C. and 30 inches barometer) are introduced, and the little plant being put in, makes the whole 102 centimetres.

Then a small amount of carbonic acid is let in, and the volume of gas oscillates during the experiment from 102 to 130 c.c., according to the temperature and barometric pressure at the time of observation.

The little plant of *Convolvulus arvensis* was introduced on the *25th July* 1893, its height being then 30 divisions of the graduated tube.

On the *26th July* it had grown to 37 divisions.
„ *28th* „ „ 44 „
„ *29th* „ „ 48 „
„ *30th* „ „ 51 „ when it began to curve.

On the *31st July* it had formed a new leaf and was curving; it now occupied 52 divisions of the tube.

On the *1st August* it had curved considerably, as all plants of the genus *Convolvulus* do, and measured only 50 divisions in height; but on the *2nd August* it had shot up again to 64 divisions.

It appeared very healthy.

On the *3rd August* it attained to 68 divisions.

On the *5th August* there were new leaves formed, and the plant measured now 70 divisions in height.

During the *6th*, *7th*, *8th* and *9th* of *August*, the plant was healthy and two more new leaves had formed.

The water being well supplied with carbonic acid, and a little of this gas again introduced into the graduated tube, I left the experiment (in order to make a journey) until the 18th September.

On the *18th September* my *Convolvulus* had grown to 90 divisions; and by the 30th of that month to 94; nearly to the top of the tube.

On the *2nd October*, it began to turn yellow, *as did also the two plants growing in water outside the apparatus as "witnesses"*; they all three put on their autumnal tints at the same time, and had ceased to vegetate by 30th October.

The gas in the graduated tube (reduced to 0° C. and 30 inches barometer) then measured 95 cubic centimetres. It was analysed on the 30th October, and gave exactly the following result:—

Nitrogen, . .	75 cubic centimetres.
Carbonic acid, .	none
Oxygen, . .	20 ,, ,,
Total, . .	95 ,, ,,

Thus in the course of three months and seven days, or ninety-eight days, the little plant had grown from 30 to 94 divisions, not counting the curve, natural to the *Convolvulus*, and had converted all the carbonic acid into oxygen, leaving the nitrogen exactly as it was at the commencement of the experiment.

At the end of these fourteen weeks the atmosphere of the graduated tube was richer in oxygen than ordinary atmospheric air.

II.—ADDITIONAL NOTES.

1. Rumbling Thunder.—There is a curious passage in Galvani's paper, *De Viribus Electricitatis*, etc., 1791 (Bologna), on the use of a frog's leg, properly prepared, as an electrometer, or electroscope.

Dr. Galvani wished to try whether the electricity of the atmosphere, or the clouds, would produce the same effect on the prepared limbs of a frog as is produced by the artificial electricity of ordinary machines. He had already noticed, independently of the convulsions caused by the direct contact of the limbs with the conductor of an electric machine, that whenever a spark was taken from a large conductor *situated at some distance* from the prepared limbs, the legs moved with a kind of spasmodic contraction, sometimes strong enough to cause them to jump a little.

In order to ascertain whether atmospheric electricity would act in the same manner, he placed a conductor at the top of his house in Bologna, and put this conductor in connection with the prepared frog placed upon a table in the open air, or enclosed under a glass bell, and he soon observed that lightning produced the same effect as the sparks of an electric machine at a little distance. The same contractions of the limbs occurred, and they were stronger, or weaker, according to the distance and quantity of the lightning.

Thus far the effects might, naturally, have been expected;

but a remarkable circumstance was observed which seems to explain another phenomenon of nature: it was found that instead of one contraction at every clap of thunder, the frog's limbs were affected with a sort of tremor, or succession of convulsions, which seemed to be nearly equal in number to the repetition of the thunder, namely, that succession of explosions which cause the rumbling noise of thunder. This observation, he imagined, proves that the rumbling noise is not the repeated echoes of a single explosion, as had been generally admitted, but that it is produced by a quick succession of several explosions. This is, no doubt, very true; but the effect of echo may likewise play its part, as Galvani himself would have admitted could he ever have heard a pistol discharged on a Rhine boat passing the famous Lurleyberg on a fine summer day.

2. Booming Noises in the Air.—I have, on more than one occasion, whilst sitting of an afternoon on the sand-hills of Ostend on hot, calm days of summer, heard booming sounds in the air, *just like the reports of distant cannon.* This subject gave rise, many years ago, to some correspondence in certain geological journals, and it was sought to prove that what I had heard so distinctly, was really due to the sound of cannon, during artillery practice carried by the water from the English or French coasts.

However, I have since met with accounts of similar sounds being heard in South America, and in India, at places where no sounds of cannon could by any possibility be heard; and these singular booming sounds, which only occur in the calmest weather, when there are no clouds,

and no wind, still require explanation. At the time I first heard them, I took every means of assuring myself that they could not be due to ship's guns at a great distance, or to artillery practice hundreds of miles distant. Moreover, I never heard them more than twice or three times in an afternoon. Still, from the nature of the sound this, in the present state of science, would be the only explanation possible, had I not met with accounts by travellers in South America, and India, of precisely similar effects having been noticed by others under circumstances that precluded the idea of their being reports of guns at a great distance.

3. Latest Observations on Atmospheric Electricity.—A history of these observations is given in my work *Familiar Letters on Some Mysteries of Nature* (1877), and in my previous work *Phosphorescence* (1862). Since the dates at which they were published, many thousands of observations have been made, confirming all that is there stated, but adding no new discoveries of importance. The recent work of the Austrian philosophers, Elster and Geitel, on the higher Sonnblick (about 10,000 feet above sea-level), add little or nothing to what was known in the time of François Arago (*Notice sur le tonnerre*, 1838). They have found, at this height, that in storm-clouds there is a change in the sign of the electricity after every flash of lightning, just as we observe in the plains or valleys. They also find, that *St. Elmo's fire* is a constant accompaniment of storms, and is sometimes *positive* and sometimes *negative*—not more frequently one than the other. Negative St. Elmo's fire follows *bluish* lightning, and positive St. Elmo's fire follows

reddish lightning. This fact was frequently confirmed; whence these observers conclude that the *direction* of the electric current which traverses the atmosphere appears to have an influence on the *colour* of the lightning.

To this I may add, that whenever I have witnessed a stroke of lightning, it has always appeared as a *red* globe, about the size of a cannon-ball, which, taken in connection with the fact that the Earth is always negative, is worthy of note. Nevertheless, it is known that the electric spark is of various colours when passing through different gases, being very white in carbonic acid, reddish or purple in hydrogen or ammonia, etc. Hitherto, without the aid of direct experiment, I have thought that blue lightning occurred in dry air, and red lightning in wet air.

In 1889, M'Lean and Goto, in Glasgow, showed that an enclosed mass of air is electrified *negatively* by the burning of a paraffin lamp, coal-gas, sulphur, magnesium, and many other substances. But the burning of *charcoal* electrified a room *positively*. When ventilation is active no electrization of the air of a room is perceptible by these means.

4. Smoke in the Air of Towns.—Dr. Cohen of Leeds has calculated that in that town alone, about *one ton* of smoke is launched into the atmosphere *every hour* (the exact figures found were twenty tons a day). A large amount of this falls as soot, darkening the air, and fogs, and blackening the skins of men and the leaves of plants. He finds in this soot 14 to 15 *per cent.* of what he calls a "nasty, sticky oil," which has an unpleasant odour, and causes the soot to adhere so firmly to the leaves of plants, that it requires an immense amount of rain to wash it off. The carbon and coal-oil of

soot, nevertheless, act as antiseptics, and are not so harmful as many people suppose.

5. The Dust Theory of Rain.—Of late years a new theory has been put forth regarding the formation of mist, fog, cloud, and rain. It is asserted that without dust in the air—that is, microscopic fragments of sand, sea-salt, organic matter, etc.—there would be no mist or rain. The starting-point, it is said, of each *drop of water* is a minute nucleus of dust—an infinitesimally minute fragment of salt or sand; "a microscopic speck of sand, around which the vapour of water condenses," as a man puts on an overcoat. Without this dust, which is always present in the lower atmosphere, the vapour of water, on a cooling of the air, would be deposited on the ground in sheets of dew that would soak the buildings, and gardens, etc., but there would be no mist, fog, or rain.

This theory is based upon a simple experiment, which consists in exhausting some air from a large glass globe full of moist air. If that air be perfectly free from dust, no mist is formed when the air is thus cooled; but if a little dust is blown in, mist forms as soon as the piston is worked again.

It is probable, however, that electricity may be capable of forming mist or fog in perfectly pure air saturated with moisture. When ozone is passed through water into air, confined in a glass vessel, a mist is formed in the latter, whether there be any dust or not.

6. Odour of the Atmosphere.—In addition to what I have already said on the odour of the air, experienced in travelling from one country to another, on the odour of the

air after a summer shower, on the fact that ancient fossils of the tertiary period have revealed to me that sea-air had the same odour as now in times excessively remote, I may record here that, according to Dr. Varigny, the atmosphere itself, which is generally considered to be *inodorous*, really has an odour *sui generis*. In his opinion the air that usually surrounds us is full of all kinds of scents and odours, but we are so accustomed to them that they attract no attention. But after spending some time in an atmosphere where the most ordinary odours cannot gain access, and then returning to our ordinary surroundings, the case is altered and a very powerful odour is perceived. This fact has been noticed by various observers who have sojourned for a considerable interval in deep caves. The air of these caves is nearly odourless, and when, after a few hours spent in this "scentless air," the visitor emerges into the open air of the country, he perceives that the atmosphere has a peculiar and very intense odour, by which delicate people in these particular circumstances have been, more or less, strongly affected.

But, after all, it is not the atmosphere itself which affects the olfactory organs in these circumstances, but the numerous extraneous substances that are constantly present in its lower strata. So that Dr. Varigny's supposition that the atmosphere has an odour *sui generis* is by no means proved.

7. Free Oxygen in River Water.—The amount of *free oxygen found in the air dissolved in river waters* varies according to the purity of the water. In the absence of impurities, there is far more oxygen than when impurities are present; and we can determine the degree of purity of a

river water by simply ascertaining the amount of *free oxygen* which it contains.

For instance, the Thames at some distance above London yields 7·4 parts of free oxygen, at Hammersmith 4·7 parts, at Somerset House 1·5, and at Woolwich 0·25. These figures speak for themselves.

Most river waters yield from 4 to 8 cubic centimetres of free oxygen gas per litre (or quart) of water, according to circumstances. The more oxygen gas thus found, the purer is the water, and better for drinking. The pure water of the Rhone, far from towns, will give 8·4 cubic centimetres of oxygen gas to the litre of water, whilst the water of the river Seine at Paris only yields 3·9 cubic centimetres.

8. Importance of the free Oxygen Ratio in the Air.—In a recent pamphlet on *Air and Life*, Dr. Varigny states that living beings are adapted, at the present period of the life of the globe, to exist in an atmosphere containing $\frac{1}{4}$ of oxygen, and $\frac{3}{4}$ of nitrogen. Experience shows that if the ratio of oxygen be decreased even by $\frac{1}{4}$th part, life can no longer be maintained. Paul Bert has shown that a change in the contrary direction is, also, most deleterious. If the oxygen acquires a certain tension in the atmosphere—or, what amounts to the same thing, if it be present in a certain ratio above the normal—it becomes an agent of death, both for plants and animals. This he demonstrated by causing plants or animals to live in a normal atmosphere, but under a high degree of pressure; or by placing them in an artificial atmosphere containing a large excess of oxygen. In both cases death was the result.

9. OZONE IN THE ATMOSPHERE.—The absolute quantity of ozone, or condensed oxygen (3 volumes condensed into 1), rarely exceeds 1 part in 10,000 parts of air.

Its presence is a fair guarantee of the purity of the air, but an excess of ozone is deleterious to persons suffering from bronchitis.

Ozone has been liquefied at 100° C. below *zero*, with a pressure of 127 atmospheres. It then forms a liquid of a dark indigo-blue colour. Gaseous ozone, viewed endways through a tube a yard long, also shows a blue colour.

10. WATER VAPOUR IN THE ATMOSPHERE.—The average quantity of water vapour in the air near sea level, in most countries, is from 60 to 75 *per cent.* of that required for complete saturation.

The phenomenon of the rainbow proves that rain-drops are perfectly spherical in form; for this phenomenon can only arise from the regular dispersion of white light by transparent globules of a perfectly spherical shape. Instantaneous photographs also show them as perfectly globular in form.

Observations made, of recent years, from the earth, on mountains, and in balloon ascents, have shown that the tower of a cumulus cloud often exceeds 10,000 or 15,000 feet, and in great storms may be 25,000 to 40,000 feet from base to summit.

11. LATEST CONSIDERATIONS ON "ARGON."—Lord Rayleigh has said, "We are not able to state with certainty whether argon is a mixture, or, if it be, of how many elements it consists. The spectroscopic evidence points in

favour of at least two components, but of itself is not conclusive." And, again, "the density of argon is approximately 20."

This causes me to believe that argon may ultimately be found to be a *carbide of nitrogen*, CN, having half the quantity of carbon contained in cyanogen. Such a compound would have a density of 20, and may yet be artificially prepared in the laboratory. This, in spite of the fact that considerations, derived from the specific heat of this new gas of the atmosphere, show that it must be considered an element, according to our present experience.

"*Helium*" is another gaseous body, which is still under investigation by Dr. Ramsay, and this chemist has recently (1898) found still another gas, which he calls "*Crypton*" (or "hidden"), and has obtained as a *residue from the evaporation of liquid air*. He believes it is present in the atmosphere to the extent of 1 part in 20,000 parts.

The new gas "Argon" is found to form about 1 *per cent.* of our Earth's atmosphere, and, like nitrogen, has little or no affinities for other substances. It was first seen by Cavendish in the last century, and by Van Marum, a Dutch chemist, when they subjected atmospheric air to the action of the electric spark, with the view of obtaining nitric acid. There always remained a residue in these experiments, and this residue consisted largely of "argon," together with the other gases which had escaped the action of the electric sparks.[1]

12. High Readings of the Barometer due to the

[1] A letter published in the *Chemical News* of 17th June 1898 shows that Rayleigh and Ramsay have really isolated no new elements, but only *mixtures* of gases.

MOON'S ACTION.—I have sometimes been surprised at the remarkably high reading of the barometer extending over a month or more in England, and Northern Europe generally, and independent of the direction of the wind or state of the weather. Such was the case, for instance, in January and part of February 1896. This phenomenon has been carefully observed by Mr. Dechevrens, of Jersey (director of the St. Louis Observatory in that island), and he attributes it decidedly to cosmic influence, that is, to the position of the Sun and Moon with regard to the Earth, and especially to the distance of the Moon : *the greater the distance of the Moon the higher the glass stands*, and the nearer the Moon is to the Earth, the lower the barometer.

The Moon acts upon the atmosphere as it does upon the ocean to produce *the tides* ; and the nearer our satellite happens to be to the Earth the greater is its attraction, and the lower the barometer.

By studying the fluctuations of the barometer since 1750 to the present time, Mr. Dechevrens has discovered that this *high reading* has a period of 19 years, and in making these researches he has, moreover, discovered a general increase of atmospheric pressure having 63 years between the *maximum* and *minimum* points, or a cycle of 126 years.

13. HYDROGEN GAS IN THE HIGHER REGIONS OF THE AIR.—It will be remembered that one of our greatest chemists, the late Professor T. Graham, who was for some time Master of the Mint, discovered a small quantity of hydrogen gas in meteorites (aërolites), composed chiefly of iron and nickel, more especially on the Leanarto meteorite, which

contains 90 parts of iron and 8 parts of nickel, with a little cobalt. When heated in a porcelain tube a quantity of hydrogen gas, amounting to about double the volume of the meteorite, was obtained. Hence he concluded that meteors traverse a region of the heavens in which hydrogen gas is contained; and he calls attention to the fact that the rays of hydrogen have been found in the spectra of certain fixed stars, and in the sun.

The conclusion is not warranted, as this remarkable aërolite was, like all others, at an excessively high temperature on passing through the air, and as our atmosphere, at least in the lower regions, is abundantly supplied with vapour of water, which would instantly be decomposed on the aërolite entering these lower regions, the conclusion is not necessary. It may be, also, that the hydrogen found in his experiment was simply due to the absorption of water into the pores of the meteorite after it had fallen, which water would be decomposed when the meteorite was heated in the porcelain tube, and yield hydrogen gas.

14. Electric State of the Air during Cholera Epidemics.—We must not pass over the very interesting results obtained by Professor Denza at the Observatory of Moncalieri in Italy, during an outbreak of cholera, which was very severe at Turin and other towns of Piedmont in 1867.

These observations on atmospheric electricity by Denza were commenced regularly in December 1866, and were the first regular researches of this kind carried on in Northern Italy since Beccaria made the first experiments on the electricity of the air in fine weather about the

year 1775, in the days of Benjamin Franklin and De Saussure.

In these researches the tension of the atmospheric electricity was determined by Denza with the bifilar electrometer of the late distinguished Professor Palmieri, of the Royal University of Naples. During the months of August and September 1867, *when the outbreak of cholera was at its height* in Turin, the *electric tension of the air fell to almost nothing*, except on two days when there occurred storms (*temporali*).

15. Liquid Air.—The liquefaction of gases by the application of cold and pressure combined has occupied many experimentalists for the last century, or more. It has now culminated in the liquefaction of atmospheric air by Professor Dewar of the Royal Institution.

The curious chemical properties of this new fluid have been alluded to already, but its physical property as a motor power is no less wonderful.

Liquid air is simply the air we breathe compressed in a series of cylinders, each successive cylinder pressing the air into a smaller and smaller compass, the air after each pressure passing through cooling tanks until, finally, when squeezed into about $\frac{1}{800}$th of its original volume and cooled to about 312° below the freezing-point of water, it changes from a gaseous state into a liquid.

When this liquid is again exposed to the ordinary temperature of our rooms or streets, it expands to its original volume with such power and rapidity as to exert a pressure of more than 12,000 lbs. to the square inch, which is a truly explosive force exceeding that of dynamite itself.

One gallon of liquid air weighs $7\frac{2}{3}$ lbs., and we are assured that, in round figures, about 1 lb. of coal is required to make 1 lb. of liquid air. Hence it must be a very economical source of power.

It has been asserted that one cubic foot of liquid air will develop, on gradual expansion, $5\frac{1}{2}$ horse-power per hour, or 1 horse-power for $5\frac{1}{2}$ hours; and it is believed by some practical men, that this enormous power will soon supersede steam, electricity, and all other sources of power, and that it can be controlled and managed as easily as any of them.

To make liquid air is one thing, but to devise machinery for its utilization as a motor power is another; but both these results, I am told, have been recently carried out by an Anglo-American firm, which has already placed on our streets motor cars driven by the gradual expansion of liquid air confined in a powerful cylinder; and there seems some probability of liquid air being produced cheaply in large quantities and applied economically as a motor power in various branches of industry.

16. Field Lightning.—I find that the singular phenomenon described in my *Mysteries of Nature* as *Field lightning*, and alluded to in Chapter IX. of the present work, has been witnessed in Mongolia as well as in the Jura Mountains. Mr. A. B. Freeman Mitford, C.B., in a work on Peking, issued quite recently, describes a storm he experienced in Mongolia on 7th May 1867. He says: "About two miles from Llama Miao, where the storm had lashed itself to its greatest fury, we came to a small plateau surrounded by low hills. Here we witnessed a phenomenon, new to me, and which I certainly never wish to see again. The thunder, which

seemed to circle round the hills, roared savagely and cracked with deepening peals, while *the lightning ran along the ground, criss-crossing in every direction, until the little plain was covered with a perfect network of blue liquid flames, from the meshes of which escape seemed impossible.*"

APPENDIX B.

Outlines of a New Atomic Theory.

By Dr. T. L. Phipson, F.C.S., etc.; read at the *British Association for the Advancement of Science*, Sept. 1886.

In what follows, the term *phlogiston* is used in a somewhat different sense to that in which it was employed by the older chemists. Some other term might have been equally acceptable, but this one already belongs to chemistry, and therefore we have a predilection for it.

On a general survey of organic and inorganic nature, our attention is arrested by a number of facts, which, though they have hitherto defied explanation, the present considerations appear to account for, so far as we can account for anything by connecting facts with theory. Nevertheless, the theory we now put forth does not necessitate any great change in the nomenclature or teaching of chemistry; if it represent truth, it should be given to the world, though for many years we have hesitated to publish it.

In chemistry we have an immense list of substances, all of which present themselves as colourless fluids, or white powders, though differing as widely in their properties as pure water and prussic acid on the one hand, or arsenious

acid and sugar on the other. Wine-glasses filled with water, alcohol, ether, sulphuric acid, solution of potash, etc., present no difference to a child or a savage; neither would their contents be considered anything else than water if they contained a solution of some nitrate, chlorate, sulphate, sugar, strychnine, veratrine, ammonia, cyanide of mercury, and so forth. In like manner, all the metals present what is termed the "metallic aspect"; they all show a great similarity of physical and chemical properties, so that tin, silver, cadmium, zinc, antimony, sodium, magnesium, aluminium, lead, etc., would readily be mistaken one for the other by a child or inexperienced person. Again, the alkaloids, sugars, glucosides, essences, etc., all present a great similarity in their physical and chemical properties, a likeness which extends to their therapeutic qualities also.

Another fact, which has often struck chemical philosophers, but has hitherto baffled all attempts at explanation, is that of all the numerous *elements*, or simple bodies, which compose our globe, *four alone* are found sufficient to build up the whole of *organic nature*, and to form the thousands upon thousands of substances known as *organic compounds*.

One more fact, which is amply demonstrated by the numerous analyses given in one of our works, is that meteors or aërolites coming from distant regions of space bring no unknown matter to our globe; they are composed of the *same materials* as our earth. It will be seen by what follows that the same materials may possess *different properties*, according to the circumstances in which they are placed.

A phenomenon, readily explained by our new atomic theory, though it has hitherto not been accounted for satisfactorily by any hypothesis, is that observed when two substances of heterogeneous natures, such as two metals, are brought into contact, an electric current, or electric, calorific, or magnetic manifestations, immediately occur.

The old notion that matter is composed of "atoms and spaces" is doubtless correct, and it can be argued successfully that atoms are extremely minute spheres. When one substance is divided by another (as when an apple is cut by a knife), the latter passes between the atoms, for *matter is impenetrable*, that is to say, the same space cannot be occupied at the same time by two groups of matter or by two substances; one must make room for the other, and the *space between the atoms* is what we designate as *phlogiston*.

The whole question of the atomic constitution of matter is contained in the theory of equal gaseous volumes, or better, of the *combining volumes of matter in the state of gas*. When we consider this subject, we are met at once by a dilemma. Physical experiment having shown that between certain limits of temperature equal gaseous volumes dilate or contract equally for equal amounts of heat or pressure, it was argued that equal volumes of gases contain the *same number of atoms* of the *same size* and placed at the *same distance* apart. This, of course, implies that the atoms are of *different weights* (for instance, the atom of H weighing 1, that of N weighs 14, etc.).

But it soon came to be seen that this could not be, because in equal volumes of certain compound gases we know that there cannot be an equal number of atoms.

The next supposition was that the atoms in equal gaseous volumes may be of *different sizes.* Thus the atom of H would be 14 times smaller than the atom of N, etc. There is nothing to be said against this hypothesis, except that it does not explain anything; it merely asserts that the atom of N is 14 times as heavy as the atom of H, because it contains 14 times more matter. This notion is, on many accounts, improbable, unphilosophical, and explains nothing. But another proposition, which we shall now put forward, does explain a number of phenomena that otherwise we find it impossible to account for.

This proposition is that equal gaseous volumes contain a *different number of atoms* all of the *same size* and *same weight.* This implies that the atoms are all of the *same nature*, and proclaims the *unity of matter.*

Whatever substance may be under consideration, its atoms are all of the same nature, and they are separated by space, which we call *phlogiston*, a term that implies movement, light, heat, electricity, etc. The greater the amount of *phlogiston* the greater the *energy* of the system of atoms termed *element.* Thus H is the most energetic system of atoms yet known; it has the greatest amount of phlogiston; in other terms the motion of its atoms is the most extensive.

The matter of all the *elements* is therefore identical; *the phlogiston alone varies*, that is, the *distance* or *space* between the atoms (considered at rest), or their *extent of motion.*

A chemical *element* is therefore a *system of atoms*, the nature or properties of which system depends on its phlogiston, and the amount of the latter is deduced directly from the balance—from the *weights which combine*

together. Thus in equal gaseous volumes of H, N, Cl, etc., we admit that there exist, say, 10, 140, 350 atoms of the *same size, same weight,* and *same nature*; and if we could volatilize without decomposing solid bodies such as sulphate of iron, for instance, so as to consider them under the same gaseous volume, we should find the same law hold good for them, and that an equal gaseous volume of ferrous sulphate, for example, would give, as compared with the substances above-named, 760 atoms of the same nature as those of H, N, or Cl.

It will be seen by this that the *properties of a substance* depend not on different kinds of matter, but on the different amounts of *phlogiston* that separate the atoms and cause them to move in certain set systems. The atomic system called H is different from the atomic system called N, because the atoms of the latter system are separated by less space; the system possesses less phlogiston.

We thus see that, as everything depends on gravitation, the systems of atoms (elements) known as iron, oxygen, sulphur, etc., on this globe, may possess very different properties on the planets Venus or Jupiter, for instance, on account of the different distances of these planets and our globe from the sun.

Spectral analysis, like the fall of aërolites, proves that the same nature of atoms exists in far-off globes as with us; but we see that the properties of a substance depend on its *phlogiston,* which in its turn depends on gravitation, so that although the matter is identical with that of our earth, the physical and chemical properties must be different from what they are upon this globe.

We also see how the whole *organic world* is made up of

a few systems of atoms (elements) only; they are those which contain the *most phlogiston*, and consequently possess the most energy; they constitute the nearest approach to *vitality*.

Again, when two heterogeneous systems of atoms are brought in contact, a vibration ensues such as astronomers have termed *perturbation*; it is caused by a slight *deviation of the movement*—a slight *change in the phlogiston* (which may be temporary or permanent), and is carried away along a "conductor," in the form of what is called an electric current, or otherwise. In *allotropic* bodies the original phlogiston is more or less permanently modified; and could this allotropism be pushed far enough, the "transmutation" of the elements would undoubtedly ensue.

It will be perceived that this theory explains a mass of facts, which are not even alluded to in the foregoing notes; and though it leaves unaccounted for a certain number of physical phenomena, these will probably be explained in time without disturbing it.

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